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9 JUNE 1986

JAPAN REPORT

SCIENCE AND TECHNOLOGY

CONTENTS

ELECTRONICS

STATUS OF MITI'S THREE-DIMENSIONAL IC, SENSOR R&D PROGRAM

Overview of Technology

Tokyo SENSOR GIJUTSU in Japanese Oct 85 pp 58-62

[Article by Yoshihiro Morita and Isao Nakamo, members of the Yoneda group; and Kiyoshi Yoneda, group leader, and Takashi Nakakado, chief, Third Research Division, Central Research Laboratory, Technical Headquarters, Sanyo Electric Co., Ltd: "Three-Dimensional Circuit Elements and Sensor Technology"]

[Text] With the limitation on the superminiaturization of semiconductor VLSI elements becoming gradually perceptible, there seems to be a general consensus to put a limit of 0.1 μm to 0.25 μm (corresponding to about 100 megabit DRAM) on the finishing techniques that follow the existing principles.

Research, for putting the elements into a three-dimensional form, has been underway to surmount such limitations and utilize the resulting elements as superminiaturized devices, by integrating various functions into a single chip.

A three-dimensional circuit element is constructed by alternately imposing an insulation layer and an active layer that has element regions, based on the SOI (silicon on insulator) formation techniques. Therefore, in addition to the SOI formation techniques, techniques that are important for the purpose include smoothing techniques for smoothing the unevenness generated in the interlayer insulation film after the formation of the lower devices, and forming the next active layer, the through-hole formation techniques for connecting the upper and lower layers, and sturdy and heat-proof wiring techniques.

Among these, the most important topic for research is the SOI formation techniques aimed at the formation of the interlayer insulation film closest to the silicon wafers that have now become extremely high in quality and large size.

1. SOI Formation Techniques

As techniques for SOI formation, various approaches have been taken, including the research on grapho-epitaxy. (Footnote 1) (M.W. Greis, et al.,

APPL. PHYS. LETT., Vol 35, 1979, p 71) For the purpose of manufacturing three-dimensional elements, it is necessary to employ a method that takes the influence on the lower layers into consideration. Therefore, investigations have been in progress with the understanding that it is a technique, for the formation of a stacking structure for three-dimensional circuit elements. This is applicable to the recrystallization method that employs laser or electron beam, the solid phase epitaxy (SPE) method, and the overall epitaxy method.

Of these, the most widely used is the recrystallization method. Although the region of recrystallization is narrow at present, widths of 10 μm to 20 μm, it has become possible to obtain single crystals of considerably high quality.

In the SPE method, the lateral growth of the nucleus crystal into the insulation layer is several micrometers. Recently there is a report that a lateral growth of several tens of micrometers was realized, by the injection of p^+ ions into the polysilicon layer at high concentration. (Footnote 2) (H. Yamamoto, et al., Materials Research Society 1984 Fall Meeting, Boston, paper No 123, 1984)

In order to apply the overall epitaxy method to the manufacture of three-dimensional circuit elements there are many problems that have to be resolved. However, its completion is being awaited in view of these advantages: it can be treated similar to the silicon wafer, it is possible to obtain single crystals that are uniform omnidirectionally, and it is suited for use in optical sensors and bipolar elements, as the thickness of the active layers can be selected at will. On the other hand, this method has a drawback in that it has to be accomplished by piling up single crystals exclusively. Thus, in incorporating the active layer, interlayer insulation films, wiring materials, and MOS devices, it becomes necessary to construct the gate insulating film also by using a single crystal. These are required to give a good matching between silicon and lattices, and also, to lower the temperature for epitaxy.

2. SOI Formation Techniques by Epitaxy Method

In the past, investigation has been engaged actively for SOS in which silicon film is grown epitaxially on a single crystal sapphire substrate. The technique has already been completed, and some of the applied devices have been put on the market. However, due to the difference in the crystal forms of sapphire and silicon and a large misfit between these lattices, many crystal defects are created in the heterogeneous interface region, which makes it difficult to obtain silicon single crystals of high quality. After various treatments for improving the single crystal films, it is now possible to obtain films with considerably high quality.

In order to overcome the defects in sapphire substrate, there have been attempts on various materials to grow a single crystal insulation film on a silicon substrate and then growing single crystal film of silicon on top of it.

The insulating single crystal film is made of magnesia spinel ($MgO \cdot Al_2O_3$), calcium fluoride (CaF), boron phosphate (BP), zirconium oxide (ZrO_2), etc. The crystalline properties of the upper silicon layer, having the simple structure of Si/single crystal insulating film/Si substrate, and the electrical properties of the MOS or bipolar devices formed there, have been reported to have satisfactory results. (Footnote 3) (M. Ihara, et al., J. ELECTROCHEM. SOCIETY, Vol 129, 1982, p 2569; Y. Hokari, et al., IEEE, Vol IEDM 83, 1983, p 368; H. Ishiwara, et al., APPL. PHYS. LETT., Vol 40, 1982, p 66; J. Amano, et al., APPL. PHYS. LETT., Vol 45, 1984, p 112; and A.L. Lin, et al., J. ELECTROCHEM. SOCIETY, Vol 132, 1985, p 239) It becomes necessary to select materials or the method of epitaxial growth of crystals, from the overall viewpoint, in order to construct three-dimensional circuit elements.

3. Formation of Three-Dimensional Circuit Elements by Epitaxy

In order to form three-dimensional circuit elements by epitaxial growth method, selection of the materials and the formation method for interlayer insulation films, wirings, gate insulation films, etc., become important.

On the assumption that the fundamental structure of the three-dimensional element is represented as in Figure 1, the materials and the methods for stacking have been examined.

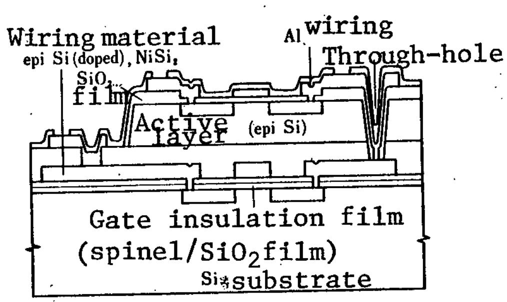


Figure 1. Schematic Diagram for Stacked Structure by Single Crystal Growth Method

Although several kinds of materials exist which can be grown epitaxially on a silicon substrate as an insulator, it is considered that the spinel and CaF_2 that have small lattice misfit, as shown in Table 1, are promising. The spinel is of cubic crystal type, the same as silicon, so that it matches with silicon lattices at the ratio of 2:3. Then, considerations on adaptability as a gate insulation film and the workability lead to the conclusion that spinel is superior to CaF_2. Therefore, we have decided to adopt magnesia spinel as the insulation film.

Further, the aluminum or polysilicon wiring that is utilized for ordinary semiconductor elements cannot, of course, be used here. Therefore, wiring is done by using single crystal silicide, or single crystal silicon film to

Table 1. Physical Properties of Insulation Materials

	α-Al_2O_3	$MgO \cdot Al_2O_3$	CaF_2	SiO_2	Si
Lattice constant (Å)	a = 4.758 c = 12.991	8.083	5.46	--	5.431
Misfit with Si	10.3 percent Si(001)/(1102)	0.8 percent	0.6 percent	--	--
Thermal expansion coefficient ($\times 10^{-6}\,°C^{-1}$)	8.40	7.45	19.1	0.6	3.6
Heat conductivity (cal/cm·s·°C)	0.065	0.035	0.025	0.003	0.20
Specific inductance capacity	9.4	8.4	6.9	3.8	11.7
Melting point (°C)	2040	2130	1373	1710	1430

which is injected a high concentration of boron or arsenic. Of the metallic silicide single crystals with high melting points, when matching with silicon lattices is taken into consideration, nickel silicide ($NiSi_2$) seems to be appropriate.

(1) Epitaxy of Spinel Film on Silicon Substrate

The general method for growing spinel epitaxially is the CVD method that we examined first. The CVD method for spinel is the method forming $MgO \cdot Al_2O_3$ on the substrate, by transporting magnesium and aluminum in the form of chlorides to an Al-HCl-$MgCl_2$-CO_2-H_2 system, and letting CO_2 react with H_2O obtained from H_2 on a silicon substrate.

As a result of careful examination of the growth conditions, a good single crystal spinel film that shows a RHEED (reflective high energy electron diffraction) pattern, as shown by Photo 1 [omitted] at a growth temperature of 950°C was obtained. The growth temperature may be lowered to about 900°C without harming the properties of the crystal. However, to further reduce the size of the devices for the three-dimensional circuit elements, it becomes necessary to lower the temperature still further. Therefore, basic examination was also given to the formation of spinel films by the MBE method that possess the possibility of lowering the temperature.

In the MBE method, use has been made of aluminum and magnesium as the supply source of metals, and of Sb_2O_3 as the supply source of oxygen. This method is the same as the method of forming a polysilicon spinel film on GaAs substrate. (Footnote 4) (R.A. Stall, J. VAC. SOC. TECHNOL., Vol B1(2), 1983, p 135) As shown in Figure 2, crystalline properties of a spinel film formed on the silicon substrate depend on the supplied quantity of Sb_2O_3. By choosing the supplied quantity of Sb_2O_3 at an optimum value, single crystal films at the substrate temperature of 810°C were obtained.

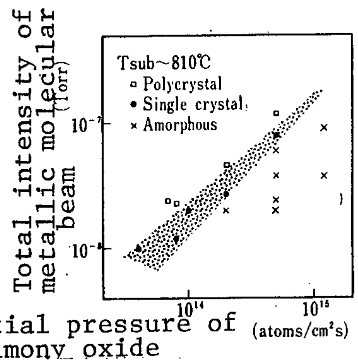


Figure 2. Relationship Between Intensity of Metallic Molecular Beam and Partial Pressure of Antimony Oxide

(2) Epitaxy of Silicon on Single Crystal Spinel Films

To form a silicon film on a single crystal spinel film partial ion vapor deposition (PIVD) was employed at high vacuum. This method is for depositing on the substrate a beam of silicon atoms that are vaporized at the electron mirror, after ionizing a fraction of the atoms at a part of the beam. Figure 3 shows the relationship between x_{min} and the substrate temperature, in the RBS measurements of a silicon film formed by the PIVD method. It can be seen that satisfactory crystal can be obtained for the substrate temperature of above 700°C. (Footnote 5) (K. Mameno, et al., Proceedings of the Ninth Symposium on Ion Sources and Ion-Assisted Technology, Tokyo, 1985, p 329) Further, for a silicon film, such as a single crystal spinel film formed by the PIVD method at the substrate temperature of 800°C, a satisfactory electron mobility of 640 $cm^2/V \cdot s$, at the carrier concentration of $5.8 \times 10^{15} cm^{-3}$, was obtained.

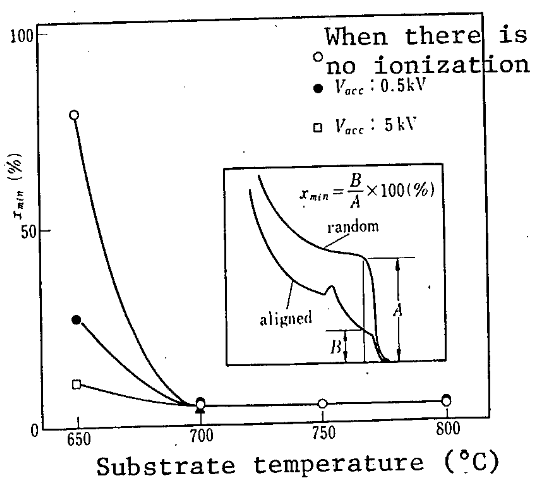


Figure 3. Relationship Between Substrate Temperature and x_{min}

(3) Gate Insulation Film of Single Crystal Spinel

Investigations have been carried out on the gate insulation films of Al_2O_3 polycrystal with the application to the nonvolatile memory elements and others. (Footnote 6) (Tokuyama, et al., MOS Devices, Society of Industrial Research, 1973) Single crystal spinel film, of the same system, can be used as the gate insulation film for MOS devices, by oxidizing silicon from above the spinel film to obtain a doubly insulating film of spinel/SiO_2, with improved C-V characteristics and surface level density (see Figure 4). Satisfactory results of field effective mobility, $\mu_p = 226\ cm^2/V\cdot s$ with $\sigma = 47\ cm^2/V\cdot s$ and threshold voltage $V_T = -0.82$ V with $\sigma = 0.56$ V, were obtained by forming a P-MOSFET (L/W = 4/10 μm) that has spinel/SiO_2 as the gate insulation film, using the self-alignment method. (Footnote 7) (Hashimoto, et al., Joint Meeting for 1984 of Kansai Branches of the Electricity Related Societies, paper G9-29, 1984)

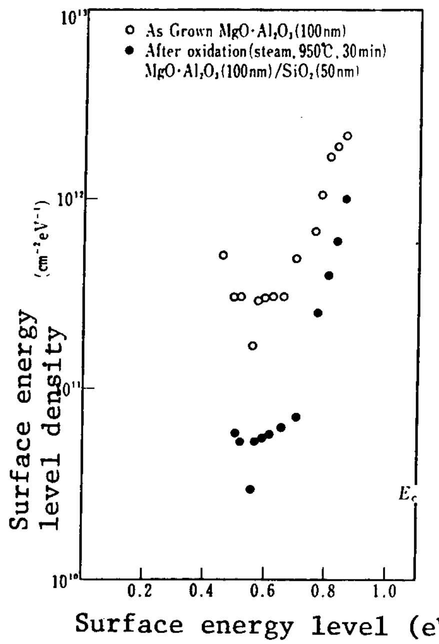


Figure 4. Relationship Between Surface Energy Level and Surface Energy Level Density

4. Optical Sensors for Three-Dimensional Circuit Elements

As an example of the application of three-dimensional circuit element, one can think of image processors. An image processor is the so-called multifunctional element that has the photoelectric conversion, scanning circuit, memory, and signal processing functions assembled in one single element. Compared with similar functions using a plurality of two-dimensional circuit elements, three-dimensional circuit elements are said to have higher speed, higher density, and lower power consumption. Examples of applications being considered are VTR camera or wall hanging TV set for household use, artificial eyeballs for medical use, FAX TV telephone for communications. Realization of these application products are being awaited.

When the pn junction photodiode and the amorphous silicon are compared as a photo sensor, the former is advantageous with respect to the responsiveness and bias voltage, but it has a problem that it has to employ a silicon single crystal film. The latter is easily layer formable even on polysilicon layer, but has a drawback that it has a slow response. Considering the common aspects of the processes used in forming peripheral circuits, other than the optical sensor, namely MOS devices, on the same plane, it is considered that the pn junction photodiode is more advantageous than the optical photo sensor. The special features of the photo-diode will now be described in the following.

A photo sensor is provided ordinarily on the top layer, and its basis is a photodiode that is formed on a silicon film, on an insulation film (SOI film). The basic functions required for a photodiode include high sensitivity, low dark current, high response speed, and others. In order to obtain a high performance capability it is indispensable to have a formation technique of SOI films, with high quality crystalline properties that permit the formation of the devices, and a formation technique of pn junction that has satisfactory electrical and optical characteristics. Further, the thickness of the silicon film in the SOI film is 0.5 μm to 10 μm, which is small compared with a silicon bulk single crystal, so that it cannot absorb long wavelength light sufficiently. While lowering the absolute sensitivity to the long wavelength side, this leads to an advantage as a substitute to the human vision since it means that the sensitivity peak lies in the neighborhood of visional sensitivity. Shown in Figure 5 is the relationship between the absorption factor of incident light and the silicon film thickness when multiple reflections in the SOI film is neglected. The figure shows that the thicknesses of the silicon film necessary for photoelectric conversion, by the absorption of 90 percent of the incident light, are 0.8 μm for blue light (436 nm), 3.0 μm for green light (546 nm), and 12 μm for red light (700 nm). An example of spectroscopic sensitivity of a photodiode, with SOI structure that has a silicon film of thickness 2.3 μm formed on a single crystal spinel film, is shown in Figure 6. The wavelength of peak sensitivity equals the wavelength of visional sensitivity, namely, λ = 550 nm, with sensitivity decreasing toward long wavelength side. This characteristic is similar to the spectroscopic sensitivity characteristic of a photodiode, on an SOI film manufactured by the laser recrystallization method, and seems to be a common feature of photodiodes formed on SOI film.

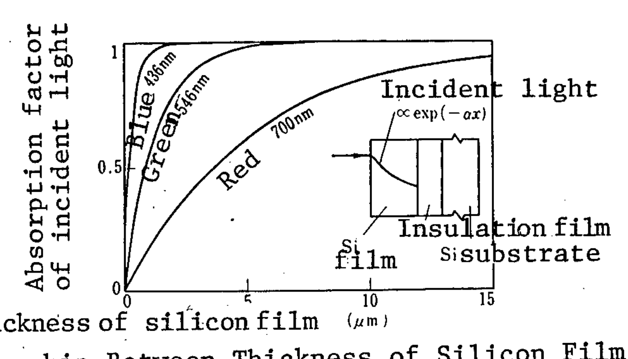


Figure 5. Relationship Between Thickness of Silicon Film and Absorption Factor of Incident Light

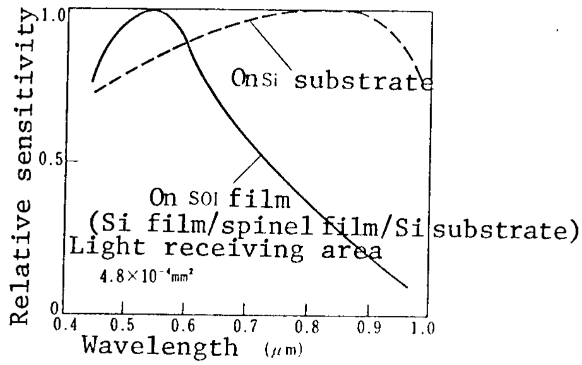


Figure 6. Spectroscopic Sensitivity of Photodiode

However, in a three-dimensional circuit element, it is anticipated that the structure, size, and characteristics of the optical sensor will be different depending upon the method of SOI film formation. The single crystal film stacking system is a system which stacks silicon film and insulation film alternately in single crystal state. The system has features that enables it to have a single crystal region with a large area over the entire surface of the wafer, obtaining an optical sensor array with high density. It gives a large degree of freedom for design without restrictions on the thickness of silicon film to be stacked. However, there is a problem in the present condition, a photodiode formed on a silicon film over a Si/spinel/Si substrate has a large dark current, so obtaining high quality SOI films will remain a future task.

A particular problem, associated with a sensor mounted on the three-dimensional circuit element, is the generation of optical crosstalk, in which light incident on the sensor layer penetrates through the interlayer insulation films and influences the lower active layer. The problem of preventing the optical crosstalk is examined. In the recrystallization system, interruption of light can be realized by interposing a silicide layer that is used as a wiring material between the upper and lower layers. On the other hand, in the single crystal film stacking system, the silicide layer to be provided is required to be single crystal and has satisfactory matching of lattice constants, since single crystal film is to be layered upon it. Therefore, the use of a silicide layer for interruption of light is considered not so easy. If a silicon film is to be used as an absorbing layer of light, it is necessary to have a silicon layer of 12 μm in order to attenuate by 90 percent the incident intensity of red light with λ = 700 nm. Providing a silicon film which is thick like this, compared with the active layer, is considered to be difficult in view of processing and performance. Therefore, it is necessary to examine an effective method other than the provision of a light interruption layer. As an example, the use of the total reflection of light at the interface of the silicon layer and the insulation film may be considered. Now, a sensor structure which will realize the total reflection of light will be considered. For solar cells, there is devised a CNR (comsat nonreflective) solar cell that possesses a high conversion efficiency, achieving more than 18 percent at AMI. The

cross-sectional structure of this element (Footnote 8) (K. Takahashi, Y. Hamakawa, and A. Tanikawa, "Power Generation by Solar Light," Morikita Publishing Co., 1980, p 154) is shown in Figure 7. By forming pyramid-type depressions, through anisotropic etching with the (111) plane, on the (100) plane of silicon surface, high efficiency was realized by generating multiple reflections between the incident plane of light and the bottom surface. Forming the so-called textured surface of the CNR solar cells by sticking the (100) plane of the silicon film over the single crystal film was considered. The critical angle for total reflection, from the interface between the silicon film and the spinel film, is 17° for λ = 400 nm and 29° for λ = 1,100 nm. As shown in Figure 7, light that is incident perpendicularly upon the bottom surface of the silicon surface reaches the bottom by being refracted by the (111) plane. The angle of incidence on the bottom surface, in this case, is 47° for λ = 400 nm and 41° for λ = 1,100 nm. The light will be reflected totally and optical crosstalk to the lower layer can be prevented. As described above, the method of preventing optical crosstalks to the lower layer, by the formation of the textured surface, may be said to have taken advantage of the single crystal film stacking system with which the control on the silicon film with (100) plane is easy. Sensitivity to the light on the longer wavelength side can be achieved at the same time since it is possible to cause multiple reflections of light by adopting the textured surface.

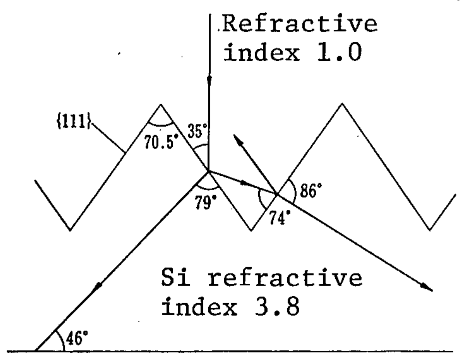


Figure 7. Cross-Sectional Structure of CNR Solar Battery

Next, an example of the characteristic features that can be realized for the first time in a sensor, provided in a three-dimensional circuit element, will be described. One of the problems in a two-dimensional imaging element is the generation of blooming and smear. Blooming is the phenomenon in which excessive charges, generated by a strong light, overflow from the picture element and leak into the transfer unit or signal line for the vertical unit to generate a false signal. Smear is a phenomenon which is characteristic to a solid imaging device in which charges, generated by long wavelength light in the silicon substrate situated at a large depth from the incident plane, are diffused and leak similarly into the vertical transfer unit or signal line to create a band-like false signal. Although these phenomena are being suppressed by various devices, more effective ways will become possible by

employing a three-dimensional structure. Namely, by placing the sensor unit and the transfer unit on separate active layers, a mixing of the charges generated in the sensor unit into the transfer unit can be avoided, so that it will become possible to form a structure which is free from generation of blooming and smear.

[Conclusion]

Development of basic techniques for realizing three-dimensional circuit elements, by means of the epitaxy method, has been carried out. A clue for realizing the heteroepitaxy of spinel films to the silicon substrate, by the CVD method, has been obtained. However, a problem remains of lowering the growth temperature, so that continued investigation along with the MBE method is needed. Further, regarding the heteroepitaxy of silicon on the spinel film, it was confirmed that growth is possible by the PIVD method at the substrate temperature of 800°C. On the other hand, for the gate insulation film of the MOS devices that form the basis of the stacking structure, it became clear that doubly insulating film of spinel/SiO_2 is effective. In the construction of three-dimensional circuit elements in the future, based on these basic techniques, it will become necessary to resolve hard problems of formation technique of metallic silicide single crystal films with high melting points, epitaxy techniques for a substrate with unevenness, smoothing techniques, and so forth.

The SOI wafers, obtained by epitaxial growth, have special features as they can be used omnidirectionally and it is possible to make the thickness of the silicon film large. Therefore, when the crystallinity is improved, it will become possible to produce bipolar elements or CCD elements, which leads us to expect the realization of three-dimensional CCD image sensors with the transfer unit in the lower layer.

The present work has been carried out as a part of "Research and Development on Three-Dimensional Integrated Circuits" which is contracted to the Association for Research and Development on New Functional Elements, Inc. based on Research and Development System for Next Generation Industrial Basic Technology of Science and Technology Agency, Ministry of International Trade and Industry.

Three-Layered Structures

Tokyo SENSOR GIJUTSU in Japanese Oct 85 pp 63-66

[Article by Kazuyuki Sugawara, member, Tadashi Nishimura, deputy leader, and Yoichi Akasaka, group leader, First LSI Process Development Division, LSI Laboratory, Mitsubishi Electric Corp.: "Three-Dimensional Circuit Elements With Three-Layered Structure"]

[Text] The improvement of the degree of integration for semiconductor elements has given an important impact on the modern society, acting as a tractor for realization of a highly developed information society. However, the degree of integration seems to have approached its limit.

In the beginning, a three-dimensional circuit element was thought to be able to surmount the limit, to increase the density of two-dimensional VLSI, by stacking two-dimensional LSI in the lateral direction. However, extending the idea further, it has become a technological development for creating entirely new "functional elements" by integrating different kinds of functional elements and circuits three-dimensionally, both in lateral and longitudinal directions, and causing them to function summarily to be able to carry out parallel operations and fast signal processing. (Footnote 1) (Furukawa, J. OF TELEVISION SOCIETY, Vol 36, 1982, p 1060) (Footnote 2) (Hayashi, J. OF ELECTRICAL COMMUNICATION SOCIETY, Vol 66, 1983, p 831)

Since 1980, Mitsubishi Electric Corp. has developed the laser recrystallization technique, in which a single crystal is obtained by squeezing the beams of the continuously oscillating argon laser, by irradiating and scanning a polycrystalline silicon layer on an insulator (SOI). Mitsubishi participated in the research and development of "three-dimensional circuit elements" contracted to the Association for Research and Development on New Functional Elements, Inc. and based on a national project, Research and Development System for Next Generation Industrial Basic Technology, which began under a 10-year program starting in FY 81. Mitsubishi carried out trial manufacture and evaluation of three-dimensional circuit elements by applying the laser recrystallization technique mentioned above. It succeeded this time in the trial manufacture of three-dimensional circuit elements in which three active layers (two-dimensional LSI layers) are stacked three-dimensionally (Footnote 3) (Sugawara, et al., Preprints for 32d Meeting of Applied Physics Society, paper No 30pC-9, 1985, p 478), as a result of the national project, and confirmed the behavior of each layer.

1. Structure and Features of Three-Dimensional Circuit Elements

A three-dimensional circuit element is manufactured according to a procedure in which an insulation layer is formed over a silicon substrate, on which an element is formed, a silicon single crystal is formed on top of it, and again an element on it is formed, and so forth. In addition, reception and transmission of signals are carried out not only by the wiring on each layer, but also between layers by means of fine holes of 1 μm to 2 μm that are provided in the interlayer insulation films, called through-holes.

As a special feature of a three-dimensional circuit element manufactured in this manner, it is high density. Second, elements are formed on insulators so that the floating capacity associated with the element becomes small, making it possible to work at high speed. Elements on individual layers can be wired three-dimensionally by the through-holes with lengths of about 1 μm to 2 μm, so that the length of wiring can be short compared with that of a two-dimensional LSI, which contribute to making the operation faster. Third, from its construction it is possible to carry out parallel processing of signals easily.

When parallel processing is carried out by connecting a multiple two-dimensional LSI's, there is a limit on the number of wirings between the

LSI's, the maximum number being on the order of 200. In the case of a three-dimensional element, parallel processing of information becomes possible by exchanging and transferring, at one time, a large quantity of information between layers, by means of several tens of thousands of fine throughholes provided. As a fourth feature, a multifunctional element can be created by integrating many active layers, by assigning different functions to each layer. For instance, an application to an intelligent image processor of multilayer construction may be considered by providing an image sensor on the top layer and arranging an operational circuit, memory, circuit-control circuit successively to lower layers, and uniting them into a single body. As in the above, a three-dimensional circuit element may be given new functions, such as high density, high speed, multiple functions, and others that could not be realized in the two-dimensional LSI in the past, so that its realization is awaited with expectation.

2. Laser Recrystallization Technique for Formation of Stacking Structure

In order to realize a three-dimensional circuit element, it is necessary to have a technique for growing a single crystal silicon layer on an insulator. In this case, it becomes necessary to change polycrystalline silicon, piled up on an insulator, into a single crystal, without damaging the devices that have already been made on the lower layers. For this purpose, there is a method in which a narrowly squeezed laser beam, or an electron beam, is projected, while scanning on the polycrystalline silicon, melted and recrystallized instantly, to protect the devices on the lower layer from being exposed to high temperatures for a long time. Requirements in applying the laser recrystallization process to the formation of a stacking structure are to protect the deterioration of electrical properties of the lower devices by avoiding damages on the devices due to direct irradiation of the laser beam, and to carry out conversion into a single crystal on top of the lower layer devices that have complicated structures.

In order to satisfy these requirements, it was decided in our company to carry out laser recrystallization with polycrystalline silicon piled up on the entire surface of the wafer, without giving such processing as patterning to the polycrystalline silicon layer. By this arrangement, it was possible to avoid damages to the devices due to direct irradiation of laser beam on the lower layers. In addition, simulation (Footnote 4) (Isu, et al., Preprints for 31st Meeting of Applied Physics Society, paper No 30aT-7, 1984, p 423) and experiment have been carried out on the temperature rise in each layer, in order to avoid damages on the devices in the lower layers by sudden rise and fall of temperature due to laser recrystallization in the upper layer, to determine the film thicknesses of the insulator layers on the foundation.

Figure 1 shows such an example. It shows the relationship between the laser power and the threshold voltage of the transistor in the case of laser recrystallization of polycrystalline silicon piled up on the MOS transistor on the substrate silicon, via an insulator film (oxidized silicon layer). It can be seen that the threshold voltage of the transistor on lower layers

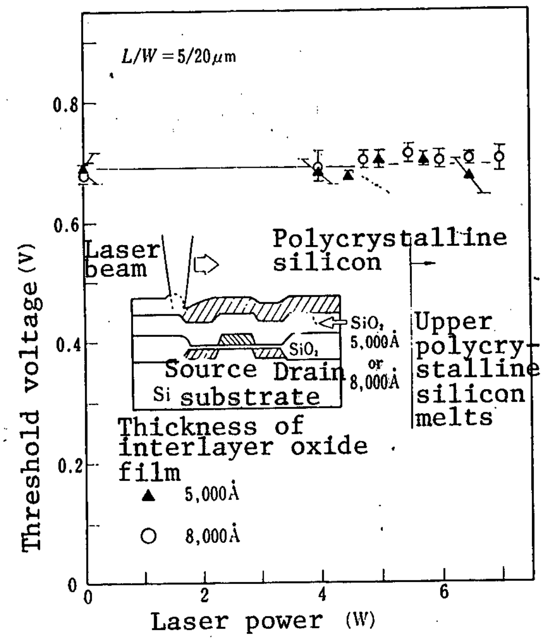


Figure 1. Relationship Between the Threshold Voltage of MOS Transistor Which Received Laser Recrystallization Processing in the Upper Layer and the Laser Power Used for Recrystallization

will not be affected by the laser recrystallization on an upper layer, if the thickness of the interlayer oxide film is more than 5,000 Å.

Next, as a fundamental method for obtaining a single crystal silicon layer on top of the lower devices that have a complicated structure, a method of selective reflection protection layer (Footnote 5) (J.P. Colinge, APPL. PHYS. LETT., Vol 41, 1982, p 346) was employed that utilizes a silicon nitride film shown in Figure 2 as a reflection protective film. This is a method by which the lateral distribution of temperature in the polycrystalline layer during irradiation by laser beam is controlled by the use of a reflection protection film. This film has a stripe pattern to control the boundary position of crystal grains.

Solidification by recrystallization occurs continuously from the silicon layer at low temperature, where there is no reflection protective film, to the silicon layer at high temperature, which is situated below the reflection protective film. Because of this, polycrystalline silicon, in the area sandwiched by the reflection protective films, grows into single crystal.

In order to apply the selective recrystallization method to the manufacture of the three-dimensional circuit elements, optimum values for the thickness of the polycrystalline silicon film, thickness, width and spacings of the nitride films, radius of the laser beams, scanning speed, and others were sought by experiments and simulations.

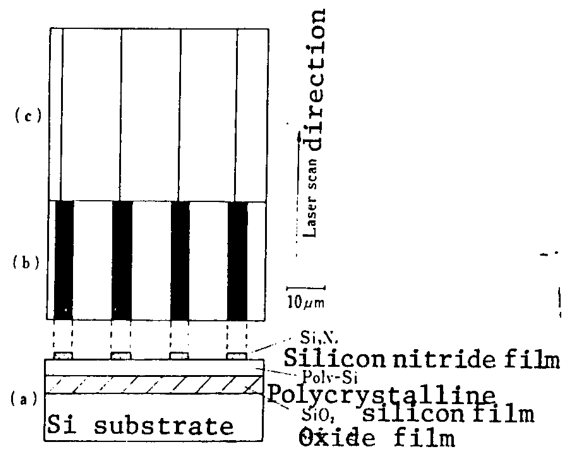


Figure 2. Fundamental Structure of Samples

(a) Schematic cross-sectional diagram
(b) Electron microgram of the surface
(c) Silicon surface after recrystallization (crystal grain boundaries are shown emphatically by seco [maybe for "secondary"] etching)

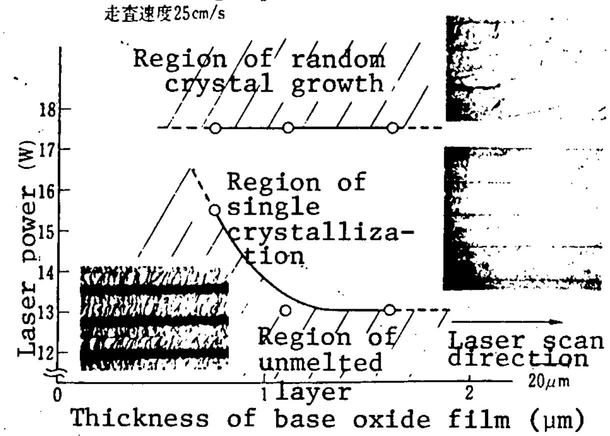


Figure 3. Relationship Between the Thickness of Oxide Film and Laser Power When the Polycrystalline Silicon Layer Is Laser-Recrystallized on Oxide Film With Various Film Thicknesses

Shown in Figure 3 are the best conditions of optimum laser power for recrystallization relative to the change in the thickness of insulating oxide film on the foundation. The photograph in the figure shows the crystal grain boundaries emphatically by means of the [second etching] method.

From Figure 3 it will be seen that melting takes place only in the area where there is nitride film and the polycrystalline silicon remains unmelted, when the laser power is low. Further, when the laser power is high, the silicon layer temperature becomes too high and the reflection protective film cannot afford to control the distribution of temperature in the lateral direction, so that there occurs random crystal growth. However, in the region of intermediate laser power, a proper temperature distribution is formed and a single crystal of 15 μm width obtained.

From Figure 3 it was found that even when the thickness of the oxide film in the devices on the lower layer is varied between 0.75 μm and 1.6 μm, the proper range of the laser power for growing single crystal in the upper layer has a large value of 2 w, so that a large margin can be set for the structure of the devices on the lower layer.

3. Trial Manufacture of Three-Dimensional Circuit Elements With Three-Layer Structure

After basic examinations, as above, a three-dimensional circuit element with stacked cross-sectional structure, as shown in Figure 4, was manufactured on a trial basis. The trial manufactured elements are N-channel MOS transistors for all of first, second, and third layers, with the formation of a silicon substrate in the first layer and SOI layer by laser recrystallization for the second and third layers. In accordance with the result of the investigation mentioned earlier, the interlayer insulation film between the first and the second layers is an oxide film by CVD method with a thickness of 0.8 μm to 1.5 μm after smoothing. The interlayer insulation film between the second and the third layers is an oxide film set to a thickness 1.4 times the thickness of the layer between the first and the second layers, in accordance with the result of an investigation similar to the above. The wiring layer, for the first and second layers, is formed with phosphorus and heavily doped polycrystalline silicon, and the third layer is formed with aluminum. The transistors on the respective active layers are able to operate independently. Each wiring layer is connected by through-holes with a minimum size of 4 μm. It is possible to carry out signal transfer between an upper and a lower layer.

In Figure 5 typical 1-V characteristics are shown. The surface picture of the transistor, and the mean and dispersion of the surface field effect the mobility of electrons measured in a 4-inch wafer, for the MOS transistor on each active layer. The electron mobility for the second and the third layers is somewhat lower than the value for the first layer. These values are comparable to the value for the ordinary substrate silicon devices.

The dispersion for the second layer is approximately on the same level as the dispersion for the first layer. However, the dispersion for the third layer is large, and it seems to be suggesting that there is still some unsolved problems left in the recrystallization technique on the wafer level. It will be seen that there is hardly any sign of influence on the first and the second layer of the recrystallization process on the upper layer. In the

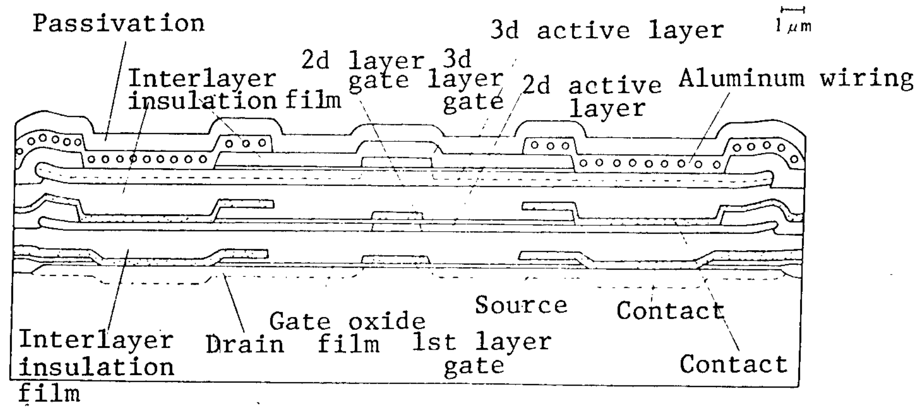


Figure 4. Cross-Sectional SEM (Scanning Electron Microgram) of Three-Layered Three-Dimensional Circuit Elements and Its Schematic Diagram

case of recrystallization for the second layer, the setting of conditions needs to be done by focusing the attention only on the device on the first layer from which a large amount of heat can dissipate. In contrast, the fact that recrystallization is possible for the third layer without damaging the second layer, which is an intermediate layer which is difficult for heat to escape, it may be regarded as showing the possibility of realizing three-dimensional circuit elements with multilayer structure of four layers or more, by the use of the recrystallization technique.

[Conclusion]

We have succeeded in the trial manufacture of three-dimensional circuit elements with three layers by means of the development of techniques that are centered around the laser recrystallization technique, obtaining a foothold for increasing the number of layers in the future. At this company, we have trial manufactured the following three-dimensional elements as a first step for confirming the stable operation of the functional elements on each active layer of the three-dimensional circuit elements and the signal transfer between the functional elements. Namely, first is a three-dimensional SRAM of 256 bits that has memory cells on the first layer and peripheral circuits on the second layer. (Footnote 6) (Inoue, et al., Preprints for 32d Meeting of Applied Physics Society, paper No 30pC-12, 1985, p 479) The other is a three-dimensional 10-bit image sensor that has a signal processing circuit on the first layer and photodiodes on the second layer. (Footnote 7) (Hirose, et al., Preprints for 32d Meeting of Applied Physics Society, paper No 30pC-8, 1985, p 478) It was confirmed that, even with a relatively large scale, these circuits can operate satisfactorily.

However, there still remains a large number of problems toward realization of three-dimensional circuit elements. It seems necessary, in the future, to have the development of the elemental techniques for SOI films--namely, techniques for enlarging the area and elevating the quality, techniques for wiring high-melting-point metals, techniques for forming fine through-holes

between layers, and so on, high-temperature and short-time heat treating technique, system designs suited for three-dimensional structures, circuit configuration techniques, and a grand unification of these techniques.

The present research has been carried out as a part of "Research and Development on Three-Dimensional Circuit Element" which was contracted to Association for Research and Development on New Functional Elements, Inc., based on the System for Developing Next-Generation Industrial Base Technology of Science and Technology Agency, Ministry of International Trade and Industry.

Design Technique

Tokyo SENSOR GIJUTSU in Japanese Oct 85 pp 67-72

[Article by Soichi Miyata, Laboratory for Giant LSI Development, and Hirotake Otake, Central Research Laboratory, Sharp Corp.: "A Design Technique in Three-Dimensional Circuit Elements"]

[Text] Research and development on the three-dimensional element (3D-IC) has seen 4 years pass by now. It is about to enter the stage in which quantitative and precise analysis and evaluation on the device characteristics, in particular, the SOI (silicon on insulator)-MOS transistor characteristics, and the electrical characteristics of circuits, in which transistors on the order of several hundreds to one thousand are integrated. This integration is based on the results of the individual elemental technique related to the device formation techniques, such as interlayer insulation film formation technique, smoothing technique, and recrystallization technique. On the other hand, optical sensors display a special feature as the 3D-IC functional device, in comparison with the existing elements what may be called two-dimensional integrated circuit elements (abbreviated as 2D-IC in what follows).

From the beginning it could have been said that, from the standpoint of the device user or the system design engineer, it places a high expectation and a heavy burden on the device provider or the process design engineer asking him to implement an optical sensor on a 3D-IC.

An attempt to realize the compounding of the image sending function, signal processing function, etc., by the stacking structure of 3D-IC, will not only promote the establishment of the basis for circuit design technique, but also the extraction and resolution of problems in the process device technique.

A design technique will be introduced for the 3D-IC optical sensor examination circuit, based on the current SOI device formation technique, in the following.

1. Why 3D-IC Sensor?

The device structure aimed at by the initial period 3D-IC sensor was a 5- to 10-layer stacking structure. As shown in Figure 1 this is similar to the structure of the cerebral skin (Footnote 1) (Joint Association for Japanese

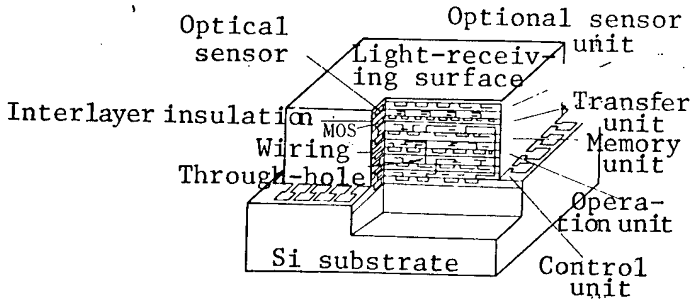


Figure 1. An Example of Conceptual Diagram of Three-Dimensional Circuit Elements

Machinery Industry and Association for Research and Development of New Functional Elements, edits. Investigation on Technical Trend Concerning New Functional Elements in FY 82, Report II--Three-Dimensional Circuit Elements, June 1983, p 83), from the viewpoint of carrying out parallel signal processing. Individual functions, such as light detection, transfer, memory, operation and control, were assigned to the respective active layers. Conceptually, it was to stack up many layers of 2D-IC's and connect these layers by means of the through-holes.

As the integration of many functions goes, considering the advancement of fine finishing techniques, it is possible to expect a sensor chip with sufficiently high functions by using 2D-IC's. Among VLSI architectures or systems that are actively studied in Europe and the United States in recent years, some 2D-IC sensors with advanced functions may be found. As an example, shown in Figure 2 is the construction of an optical mouse chip by Xerox (Footnote 2) (H.T. Kung, B. Sprool, and G. Steel, eds., "VLSI Systems and Computations," Computer Science Press, 1981, p 1). It shows the movement of the mouse chip when it traces in a one-dimensional direction, the bright line on the dark background, and the circuit construction in the chip. The sensor node is formed with a photodiode of NMOS structure, and the system constructed so as to be able to instantly carry out the binary coding processing, position variation detection, etc., in an adjacent logic unit. As a sensor device to be used in a digitized input device, like in the above case, it is indispensable that it be small in size and light in weight, and in addition, a fast processing capability of position and timing control is required. However, in a device that is closely related to human behavior, that is, in the man-machine interface, such high speed as in the digital signal processing for the ordinary audio and video signals is not required. Rather, precision and reliability of the processing are required. It is characteristic that the memory for temporary storage of the image data is not needed among the requisites for logic circuit. In other words, when image memories with high speed and large capacity are not required for a sensor chip that is to be incorporated into a device of relatively exclusive use, it may be said that it is possible to actively achieve the advancement of functions by the use of 2D-IC's.

The process of replacing the solid imaging tube by the imaging elements may be a result, for example, of attempting to advance the functions and to

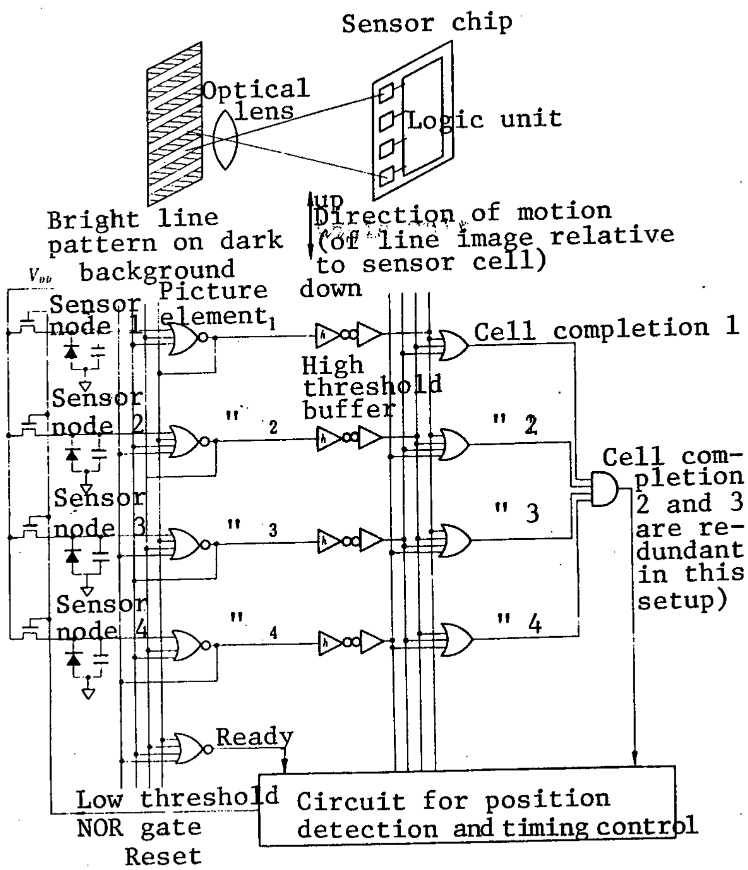


Figure 2. Detection of One-Dimensional Motion

increase the degree of integration of the optical lens system in video cameras, or of surmounting the specifications for the signal processing circuit, namely, restrictions to the image format. As 2D-IC sensors, in the case of 2/3 inch specification, there is MOS device HE97211 by Hitachi, Inc. which has picture elements of 320 (H) x 244 (V) and chip size of 8.8 mm x 6.6 mm. In the CCD device, a trial manufacture, with picture elements of 510 (H) x 490 (V) and chip size of 10 mm x 8.4 mm, has been reported by Sharp Corp. (Footnote 3) (Miyatake, et al., "490 x 510 Picture Elements CCD Imaging Elements," Technical Reports of the Television Society, TEBS 101-7, ED 842, 1985, p 37) In the future, there will be a development aimed at one-half inch, by securing the scanning lines of 490 (V). In 2D-IC sensors, with image formal restrictions, the mutually excluding requirements of increasing both the degrees of integration for higher resolving power and the light-receiving area are being steadily resolved by keeping balance with the functional aspects. These aspects include the imprisonment in photoelectric conversion factor and the improvement in the S/N. On the other hand, electronic cameras and others being spotlighted as a new field. While they are relieved of the restrictions on the image format in a sense, an ultrahigh resolving power and high sensitivity characteristics over a wide band are required, so it is conceivable that ultimate functional specifications may be brought to light.

To an inquiry whether it may be possible to replace 2D-IC sensors, put into practical use and commercialized, by 3D-IC sensors making them highly value-added and functional, there is a standpoint that gives the following answer, if one goes back to the fundamental spirit for developing the 3D-IC's.

1. As an approach for solving difficulties and barriers in the 3D-IC formation techniques, one may design and trial manufacture a functionally compounded TEG (fundamental element for evaluation). This includes sensor, signal processing function, and others to carry out evaluation of the electrical characteristics of the circuits with the scale of from several thousands to 1 million transistors, and examines the basic behavior of the circuits consisting of SOI-MOS's. Further, information obtained by the circuit design technique side, including the circuit evaluation technique, will be sent back actively to the process device technique side to have the capabilities of the circuit elements in the 3D-IC TEG on a level at least comparable to the basic capabilities of the 2D-IC sensors. The development of techniques related to the degrees of integration and the sensitivity characteristics are considered to be the common problem to both 2D- and 3D-IC, although the number of picture elements as a sensor itself is of importance. The most important point in the present stage seems to be the circuit design for 3D-IC sensors that are aimed at the crystallinity evaluation of the recrystallized layer in SOI and the functionally effective use of the SOI layers. So far, discussion has been presented on the premise of the necessary conditions for the coexistence of 3D-IC and 2D-IC. In the following, we give an examination on the premise of the special feature possessed essentially--that is, possessed for the reason of its original structure, of 3D-IC.

2. The feature elements characteristic to the three-dimensional stacking structure may be summarized as in Table 1. (Footnote 4) (Association for Research and Development on New Functional Elements, edit., Investigation on Technical Trend Concerning New Functional Elements in FY 84, Report II--Three-Dimensional Circuit Elements, June 1985, p 15) Regarding the circuit design, the fact that the logical independence of each layer in the stacked layer is high, that an organic connection between the layers can be accomplished flexibly, and that the structure possesses as latent characteristics elements of high speed and low power consumption, suggest, from the system design point of view, that it possesses a definite possibility of being placed on a chip. In addition to the sensor and signal processing function, one can imagine to store a system environment, for example, an information processing function. It is possible to incorporate a microprocessor and peripheral devices, such as memories and ports, into an on-chip system.

The three-dimensional stacking structure and the layering structure of the computer system may be compared as shown in Table 2. (Footnote 5) (Ibid., p 10) It will be seen from the table that the degree of freedom and flexibility are extremely high for such things as, which level in the logic layer can be implemented on which level in the physical level (in the 3D-IC). From the system design point of view, to have a question, such as how to

Table 1. Characteristic Elements Proper to Three-Dimensional Structure

Special feature	Content	
① Extremely small size in three-dimensional directions of SOI laminated layer	Element density given by maximum number of two-dimensional devices x N (number of layers)	High degree of integration and high density
	Optimum degrees of integration is determined by trade-offs between two-dimensional and three-dimensional technologies	
② Ample functions for organic interlayer connection	Small length of wiring (delay time) and small scatter in wiring length	Fast operation
	Through wiring between layers, tapping connection	
	Large accessibility	
	Possible optical connection	
③ High independency for each lay of the stack (in view of process, circuit, and logic)	Separation and mixing of different kinds of devices (example: bipolar and MOS)	Multi-functional (compounding and unification)
	Separation and mixing of different circuit devices (example: analog and digital)	
	Separation and mixing of different functional devices (example: sensor and light-emitting elements)	
	Division and distributed arrangement of functional blocks of logic	
	Layered arrangement of functional blocks	
④ Essentially high speed due to SOI construction	Small loading of parasitic capacity	
⑤ Extremely small power consumption required for inter-layer connection	Possible drive with high impedance	

Table 2. Comparison Between Layered Structure for Computer System and Elements of Three-Dimensional Multilayered Stacking Structure

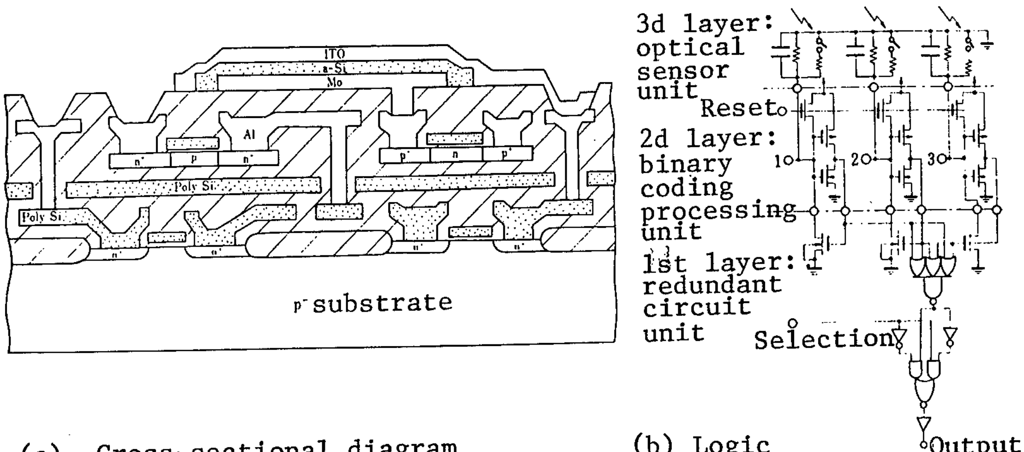
Logic layer	Functional level (PMS, ISP, and processor level)	Array processor (cystolic array), router connection multiprocessor, data flow processor	Architecture level
Logic layer	Gate level	Logic and operational function, memory function, network switching function,...	Logic circuit level
Physical layer	Active and passive element circuit level	Layered logic in memory, lamination (RAM + CAM)	
Physical layer	Active and passive element circuit level	Layered PLA/SLA, standard cell logic circuit, layered optical connection RAM, longitudinally wired router, ...	
Physical layer	Active element level	Dual gate MOS transistor (common channel layered gate), joint CMOS transistor (layered channel common gate)	

make active use of these advantages, is essentially a new kind of situation that did not exist in the 2D-IC design. The 3D-IC sensor may be positioned as one approach for establishing such a technique.

Our current approach to the solution of the problem may be regarded as probing into new requirements for 2 on the basis of the ideas according to 1. Namely, a 3D-IC sensor TEG is constructed solely by the sensor function, including the processing for binary coding and the redundant logic function for defective relief which recovers the reliability of the SOI-MOS transistor by circuit design. In the next section, the design concept and characteristic features of TEG will be described.

2. TEG for Examining 3D-IC Sensor

If the existing process device technology is to be applied to the 3D-IC formation technology for an optical detection unit, such as a photodiode of MOS type, CCD type, or a type in which photoconductive film, such as amorphous Si, is stacked. The SOI, currently under development, has a depth of around 1 μm for the recrystallized layer so that a photodiode, itself obtained by the formation of a pn junction, is an object of investigation. With this in mind, a TEG for sensor investigation was designed in which amorphous Si (Footnote 6) (J. Kudo, et al., "New Ionized Cluster Deposition System and Its Application to Silicon Films," Proceedings of the International Ion Engineering Congress--ISIAT '83 and IPAT '83, Kyoto, 1983), obtained by



(a) Cross-sectional diagram (b) Logic circuit diagram

Figure 3. Sensor TEG With Three-Layered Stacking Structure

the ICB method whose physical properties have been studied in detail for some time, is stacked as the top (third layer) as the photoconductive film. The cross-sectional structure and the logic circuit are shown in Figure 3. The optical detection unit, of the photoconductive film stacked type, may be represented as shown in Figure 3(b) in terms of dark and bright resistance determined by the dark current and the photocurrent, respectively, of amorphous Si, static capacitor formed by an ITO transparent electrode, an oppositely placed metallic electrode, and the switches corresponding to the shielding and irradiation of light. The intermediate layer (second layer) is a processing unit for binary coding with SOI-CMOS structure, and is composed of sensor amplifiers for detecting the changes in the bright and dark currents in the third layer, and reset circuits. The processing unit presupposes an asynchronous processing so that the transistor circuit is designed to reset the processing unit automatically, not only for the case of receiving reset signals synchronizing with the clock, but also for the state in which light is shielded by holding the reset terminal at the state of logic "0." However, use was made of one for the bulk Si-MOS transistor, as a circuit simulator. The simulation results of the initialization process, in the circuit for processing binary coding at the turning-on of power source, and of the automatic resetting function by shielding of light, are shown in Figures 4 and 5, respectively. In the figures, the solid curve indicates the output voltage of the processing unit for binary coding. In Figure 4, the chained curve shows the change in voltage of the power source that is turned on, and the dotted curve in Figure 5 shows the voltage at the nodes 1 to 3 of Figure 3(b). The nodes 1 to 3 are the terminals for measuring the changes in the current for the three light-receiving units, and also the voltage input terminals for confirming the individual operation of the binary coding circuits on the second layer. Moreover, they also serve as the input terminals of the pseudo-signal currents corresponding to the bright and dark currents. This confirms the joining operation of the redundant logic circuit on the first layer and the processing circuit for binary coding on the second layer, in the stacked condition for the two layers.

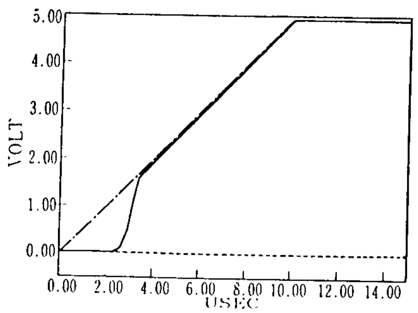


Figure 4. Power-on Reset Function for Binary Coding Processing Unit

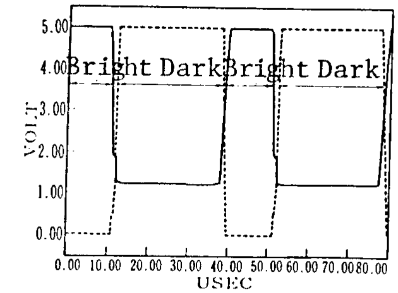


Figure 5. Automatic Reset Function for Binary Coding Processing Unit

By preparing such measuring terminals, it became possible to carry out a check on the operation of the processing unit for binary coding only, a check on the compound operation in the joint state of the first and second layers, and moreover, a check on the characteristics of the photoconductive film in the stacked state of the three layers. This permits much information to be obtained by one kind of TEG design. Summarized in Table 3 are the design specification value, simulated value, and measured value for principal items in the TEG for examination of the sensor. The following is another point in the circuit design to which attention was paid. To enhance the reliability of the circuit operation of the processing unit for binary coding, which is provided on the second layer with the SOI-CMOS construction, the three light-receiving elements are set to correspond to one picture element, and the redundant logic circuit for defect relief and the majority logic circuit are arranged on the first layer. When the selection terminal is set to logic "0," the picture element information is output in more than two-thirds of the light-receiving cells. On the other hand, when the selection terminal is set to logic "1," its output is inverted logic state. When the expected value for the first layer output, corresponding to light irradiation, can be obtained by an appropriate setting of the selection terminal, it may be judged that the upper layers are in operation. However, if no change in the first layer output is observed, even under inversion of the logic state of the selection terminal, it may be judged that the upper layers are not operating.

Figure 6 shows the waveform observed for the output voltage from the first layer for shielding the light, by the three-layer stacked construction, and inputting to the second layer the pseudo-signals corresponding to the bright and dark states. Figure 7 shows the measured values for the sensing levels of the binary coding, corresponding to the shielding and irradiation of light, under the same construction.

Table 3. Comparison Between Designed and Measured Values of a Sensor Evaluation circuit of Photoconductive-Film Stacked Type

Parameter	Designed value	Measured value
Transistor size L (μm)/W (μm) Binary coding processing unit (second layer)	P_{ch}···6/18 20; N_{ch}···6/37 E_{typ}···4.5/55 68; D_{typ}···5.5/5 7	
Mean consumed power Binary coding processing unit (V_{pp} = 5 V) Three-layer structure sensor (V_{pp} = 5 V)	Simulation: ~29 μA/cell	~30 μA/cell* ~100 μA/picture element
Operating voltage: First layer + second layer First layer + second layer + third layer	Simulation Less than 4 V to 5.3 V Same as above	3.85 V ~ 5.3 V* (confirming operation at 5 V)
Dark resistance (minimum) Two layer structure Three layer structure Optical resistance Two layer structure Three layer structure	~1.2 MΩ ~9 kΩ	1 ~ 2 MΩ* ~10 M (~5 mW/cm^2 irradiation) several kΩ to 30 kΩ* 300 kΩ to 3MΩ
Output level of binary coding (V_{pp} = 5 V) Two layer structure Three layer structure	Simulation Bright 3.4 V; dark: ~0 V Same as above	Bright: 3.2 V; dark: 0.3 V Same as above
Bright and dark states Transition time	Simulation Two layer structure several μs to 10 μs	AC measurements incomplete

Note: Measured results for two-layer structure TEG

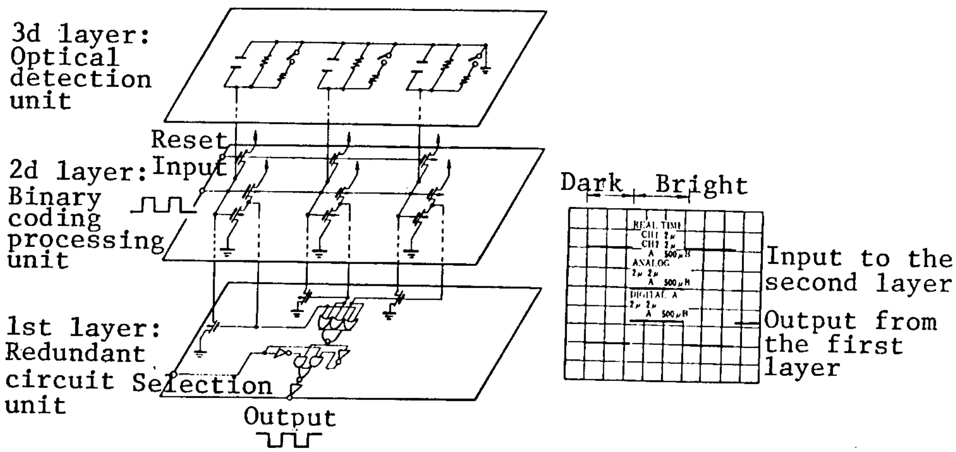


Figure 6. AC Characteristics Measured by the Three-Layer Stacking Structure TEG (psuedo-signal is input to the second layer in the dark state)

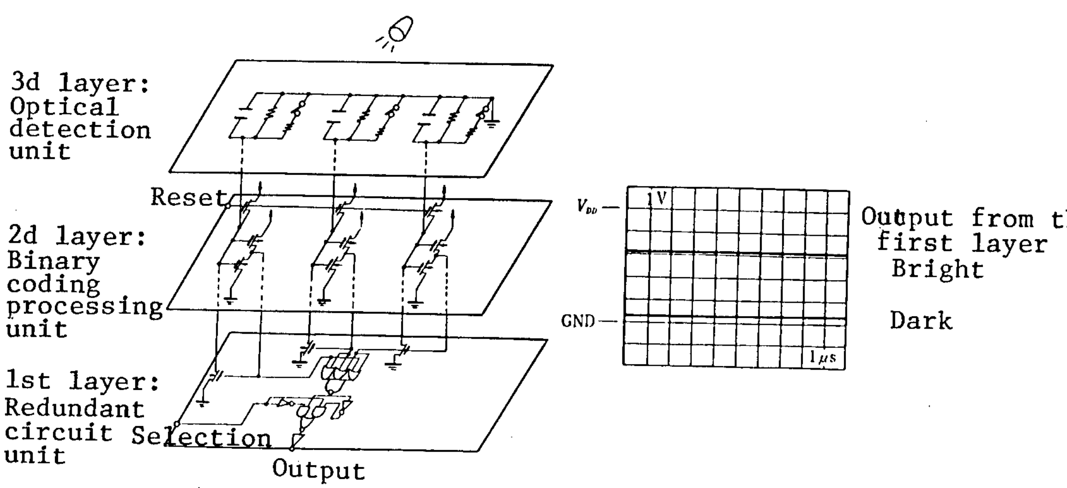


Figure 7. Optical Sensing Levels (optical irradiation and dark state) in a Three-Layer Stacking Structure TEG

A picture of a three-layered TEG chip, for sensor examination, is shown in Photo 1 [omitted]. This TEG is aimed primarily at the analysis of operation of the SOI-MOS transistor circuit. It constitutes 7 picture elements and 21 sensor cells, with a total of about 210 transistors, for the chip area of about 4 mm x 2 mm. The area of each cell is about 100 μm^2. In addition, for seven picture elements, five kinds of light-receiving windows are provided within the range of 0.005 mm^2 to 0.375 mm^2, by taking into consideration the scatter of photo-current conduction factor of amorphous Si. It is being planned that analysis and evaluation of the AC electrical characteristics and the spectroscopic sensitivity characteristics will be carried out in the future.

[Conclusion]

Based on the transient characteristics of the bright and dark responses, in the range of several μs to 1 ms, the plausibility of compounding the information processing function into the sensing function has been examined in the previous sections. It is considered that layered memories, that make advantageous use of the three-dimensional construction, and the logic circuit elements, such as routing network wiring in the longitudinal direction will be required. Examination of these individual circuit elements on the 3D-IC TEG level, based on the concept of the 3D-IC sensor system, is desired. Presently, such an examination remains in the step in which investigation on the fundamental functions regarding the optical detection and the processing for binary coding is completed. It is hoped, however, that the steps of the investigation will be advanced steadily by considering the matching between the design concept from the top down and the manufacture and evaluation of the devices from the bottom up.

The present article made reference to the creative arguments regarding the future trend of the 3D-IC that are set forth by Committee for Investigation on Technical Trend for Three-Dimensional Circuit Elements of Association for Research and Development on New Functional Elements. Thanks are due to the members of that committee. In addition, the authors are grateful to Kataoka, director, Central Research Laboratory, and Awane, deputy director, Central Research Laboratory, for their guidance and advice regarding R&D on the three-dimensional circuit elements. Finally, the present work was carried out as a part of "Research and Development on Three-Dimensional Circuit Elements" which is contracted to Association for Research and Development on New Functional Elements, Inc. based on Research and Development System on Next Generation Industrial Technology Base of the Ministry of International Trade and Industry.

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HIGH-TECH ERA TECHNOLOGICAL STRATEGY DISCUSSED

Basic Research, Internationalization

Tokyo KOGYO GIJUTSU in Japanese Jan 86 pp 5-10

[Discussion with Isamu Yamashita, vice chairman of the Keidanren (Federation of Economic Organizations) and chief investigator, Science and Technology Section of Rinji Gyosei Kaikaku Suishin Shingikai (Ad Hoc Administrative Reform Promotion Investigation Committee) conducted by Shoroku Kato, secretariat investigative officer, Ministry of International Trade and Industry]

[Text] 1. Introduction

Kato: Beginning this month, KOGYO GIJUTSU plans to invite top people in industry who are opinion leaders in Japan to discuss matters in the category "Technological Strategy in the High-Tech Era." During these sessions the discussions will be directed to the area of innovative strategy deemed appropriate for the 21st century. We asked Mr Isamu Yamashita, consultant with Mitsui Shipbuilding and Engineering Company and also vice chairman of the Federation of Economic Organizations, to be our first guest. In a governmental capacity, Mr Yamashita is the chief investigator in the Science and Technology Section of the ad hoc committee on the promotion of investigating administrative reforms. He is active on the international scene as chairman of the ISO (International Standards Organization).

2. Research Evaluation Structure

Kato: Hearings on the science and technology sector of the administrative reform investigations were held on 22 July last year. For about a year previous to that, you, Mr Yamashita, as chief investigator of the Science and Technology Section, were a witness at many hearing sessions. I wish to take this opportunity to express my appreciation for all the hard work you performed. A number of very valuable items of information were contained in your responses during the course of those hearings. Your strong recommendation that there be a shift in emphasis to a creative basic research structure was of particular interest. As a manifestation of this, there is an envigorated move to create a national research organ.

The ministry of International Trade and Industry [MITI] supports 16 research organizations staffed by about 2,600 researchers. These are evaluated in various ways. It is my view that these research organs are assigned to various time frames in appropriate categories to act as advance agents. Because of recent cuts in appropriations and personnel, we are experiencing very difficult times. We harbor doubts, therefore, as to whether we can meet the level of expectations that we have managed to achieve in the past.

Mr Yamashita, being on the front lines of industry, you have been in a position to keep in touch with the various national research organizations. You are undoubtedly thoroughly familiar with the status of these and other research organs and so have a wealth of views and opinions; you engaged in discussions involving these matters when you were a witness in the administrative reform hearings. With this as a starting point, I seek your thoughts in this area.

Yamashita: Of course, it goes without saying that research and development is the decisive factor for the future of enterprise; the crux of the problem is determination of the research and development category. Basically, research has to take precedence in order to advance in science and technology. Although it must assume priority, I believe that keeping up to date is the most important factor.

To national research organs, the various administrative needs of the respective administrative agencies are always a background consideration. So, it is true that because they are swayed by the respective basic administrative policies, the direction determines the technological and research activities.

As for MITI, its Agency of Industrial Science and Technology, while making adjustments appropriate to MITI's broad administrative needs, can undertake MITI's own major projects as well as have the national research facilities undertake other projects. In the final analysis, the most difficult undertaking for us is to make the decision to abandon research projects that have become outdated by some definitions or those that have been taken over by other research organs.

Such events sometimes cause discouragement among the research personnel. The most important function of research management at this point is to figure out ways to redirect the efforts from targets that have become less important to other objectives.

Unlike during the rapid growth era, we can no longer think in terms of unrestricted budget increases, making management the most important factor in research. Under these conditions, evaluation of research has become a function of major importance. How should this function be undertaken? The Council for Science and Technology must think in terms of evaluation of research on a national level, and as agreed upon in the legislature, this cannot be done at the expense of making evaluations at the various administrative organization levels.

In order to abandon an old research project, it is essential that praise be given to the potential of another project. It is not enough that the old

project be severely criticized; the need to make an effort in the new area must be stressed. We consider that along with providing a negative evaluation of the old project, it should be pointed out that the way money and people are assigned has become a major problem because they are in short supply, so they must be applied to projects in the areas in which they are needed most.

When such arguments were used in the Science and Technology Section to praise certain projects, it was found that they were inappropriate for government organizations. We who are in private enterprise can offer a "president's award" for superior research efforts as an incentive. Actually, presenting a "president's award" tends to stimulate the research process. Although searching out projects that have become valueless is a major objective, I am of the opinion that making a positive criticism is a very important function.

Kato: In the case of the Agency of Industrial Science and Technology, carbon fiber is an example. I do not think that on a national scale, enough positive evaluations were made. Critics made no evaluations in the domestic arena; evaluations were made overseas, and these were imported into Japan. In the area of evaluation, the methodology used in the United States differs from that in Japan. Maybe this was not good example to draw on, but we think Japan's way of making evaluations is more like the method used in Europe.

Yamashita: In the case of the United States, setting military related research aside, research projects seem to be accomplished by universities. Some of these research facilities are very large, and basically the projects are undertaken in close cooperation with the public in general. This means that unless worthy research projects are undertaken, no money will be forthcoming from the public. This point is made very clear.

A favorable aspect of a national research organ is that even if results are not obtained in a short period, there is little danger that the project will be abandoned, which keeps the whole matter in a sort of a hothouse atmosphere. Over the long term, successful results will probably be obtained. However, unless evaluations are made, there is the danger that the old research projects will drag on and prevent new research projects with good potential from becoming undertaken.

I find, therefore, that the determination of how to establish a basic evaluation structure is in itself a basic problem that must be resolved.

Although I believe that the American philosophy that unless results are obtained, there will be no money, smacks of overcommercialization and should not be basic to a national research organ, there has to be some means of evaluating the projects to keep them lively.

3. Promotion of Basic Research Having No Objective

Kato: Generally speaking, in Europe and America, the universities undertake the basic research projects that have no specific objective, while the nationally supported organs, like NASA, conduct research on target oriented projects.

In Japan, examples of the latter are the National Space Development Agency, the Japan Atomic Energy Research Institute, and the Marine Development Center. But other national research organs are not necessarily structured in that manner; they conduct basic research that has no objective much like the academic organs, while giving the appearance of conducting research aimed at an established goal. Thus the concept is somewhat different from that in other countries.

Yamashita: Although it is assumed that all research undertaken in academia is of the no-objective type, it cannot be said that all of the money distributed by the Ministry of Education in subsidies for scientific research is for research with no objective. When a professor prevails on his group to work on a given topic and then such work is evaluated by the Science Council, it is labeled with a theme. When that happens, I believe that the project loses the identity of being without an objective.

Under this definition, what is saved is the lecturer to whom renumeration is paid. This is a system that does not exist in the United States, and under a certain definition, it is classified as an expense for objectiveness research.

Funds for lecture fees, however, are not increasing, while there is a trend toward a gradual increase in research subsidy funds, which have reached considerably over the Y30 billion level. Although it is admitted that objectiveless research must be allowed to take place, the question is how to allocate funds to it. It comes down to paying a certain fixed amount for each lecture, and that becomes a subsidy system. Over and above payments made through such channels, funds are requested for specific research projects. In other words, the budget system that is in effect is not structured to accommodate objectless research.

In the American university system, Japanese enterprises are paying out some Y30 billion, none of which is earmarked for any specific project. For example, the Mitsui group gives MIT $500,000 every year. If some success is achieved, the enterprises that were donors over that period may be given some priority privileges, but otherwise the project becomes a scholarship paper for public consumption. If there is no patent involved, the contents of the paper become public property and merely contribute to the overall "know-how." So, in such circumstances, funds can be considered as allocated to objectiveless research.

If it is asked whether that system is applicable to Japan, the answer is no. In Japan, if funds are donated by the general public to a university, the Ministry of Education steps in and deposits such funds in the national treasury. If the donor objects to that disposition and requests that the funds be left with the university, the university's treasurer must make detailed accounting of where the money came from and how it was spent, permitting no discrepancy. If that extra money had not been brought in, a simple report showing how the budgeted funds were disposed of would have sufficed; but when an unappropriated sum of cash is brought in, the administration office is put to extraordinary additional work to account for its disposition in minute detail. In other words, the system itself is not conducive to unfettered research. The result

is that in FY83, private enterprise made donations amounting to only Y13.8 billion to Japanese universities, but donated over Y30 billion to American universities. This constitutes an important factor. We believe that it behooves the Ministry of Education to look into this problem and include it in the background material for a bill promoting the intermingling flow of research.

4. Technological Cooperation

Kato: Japan must offer technological cooperation to the developing countries. In the policy agenda for the coming year, MITI has included two projects: automatic translation and local energy. It is being demanded that these two categories be undertaken as major ODA international research cooperative efforts with the developing countries. A number of other projects will be undertaken separately, but these two indicate that additional efforts will be made in this area.

Yamashita: I believe that you, Mr Kato, listened to a number of things that LDC [less developed countries] representatives had to say at the recent general meeting of the ISO.

From time to time, mistakes are made, but regarding industrialization, it is essential that advances be made one step at a time. Even where the time factor is an important consideration, in climbing the stairs, it must be remembered that technology cannot be advanced when stairsteps are eliminated.

It is essential that stairs similar to those that Japan climbed step by step be negotiated. Japan climbed stairs in 30 years that it took Europe 100 years to negotiate; Korea is attempting accomplish in 15 or 20 years what it took us 30 years to do. In the beginning China seemed to think it could skip steps, but after giving the matter further thought, it came to the realization that it could not. In the industrialization process, the most important factor is to proceed as fast as possible without stepping wide of the steps or stumbling on the climb to the top. Recognition that this point is basic is absolutely essential in my opinion.

The countries in Southeast Asia that have achieved success have all observed this stipulation.

In this context, I believe that standardization is the most fundamental element. I think that the first step in a country's industrialization process is standardization; it is the essence of quality control. This is an absolutely essential element and must equate to the first rung of the ladder. The country that fails to recognize this will find that the ladder it has put in place will topple over.

I believe that in cooperating with the LDC, this is the most important factor for Japan to keep in mind. Therefore, we should offer every assistance possible in the standardization process, and using that as a base, insist that quality control be studied.

With that accomplished, we can enter into the actual technological phase. Without foundations of standardization and appropriate quality controls, presentation of charts and explanations of know-how would be of little value.

On that premise, we think that the cooperation with foreign countries should be reviewed. It seems to me that the less developed countries seriously launched industrialization, and are now finding themselves mired in a dilemma.

Because the LDC themselves have become aware of this situation, I think we should help them undertake standardization and quality control activities; I don't think such a program will cost too much money.

Kato: I agree. We have asked the JICA and others to cooperate vigorously in standardization and quality control projects. In the spring and fall of each year, 20 to 30 persons from the less developed countries are invited to participate in educational courses on a semiannual basis. Because this has been going on for almost 10 years, the preliminary groundwork should have been accomplished and the project's roots should be taking hold.

5. The Japanese and Technology

Yamashita: Early this month, I gave a commemorative lecture at Newcastle University in England on the subject "The changing Industrial Structure and Employment." In the course of the presentation, an Englishman said, "The Japanese seize foreigners' ideas and immediately industrialize them: this does not happen in Europe. What is the major cause of this?"

First of all, the cause can be found in the respective society's evaluation structures. In England, the scientist is held in high social esteem; hence there is no engineering department at either Cambridge or Oxford. Graduates of those institutions are all scientists. In Japan, technology is something that is taught in what are called higher specialized schools and in technical colleges. Consequently, because graduates of Cambridge and Oxford are classed are scientists, they engage in basic scientific research, and this is the reason for the large number of Nobel Prize winners among Englishmen. But they are not called engineers but technicians, and technicians rate lower on the social scale.

Historically, Japan has placed a great deal of value on skill, since even before the Tokugawa era. The caster of the great Buddha, the carpenters who built the Todai Temple and various shrines are given high praise. Those who build or make things have been rated higher than those who designed. This way of evaluating technology has continued over a long period in Japanese society, and even today the engineer is rated above the scientist in Japan. Japan is the only country in the world in which a person could be designated a national treasure solely on the basis of possessing a skill and in which there can be an abstract cultural asset. Japan has a custom of viewing skill with reverence and hence holding technology in high esteem.

Differences between America and Japan may be seen in the fact that in America an item is evaluated on the basis of its functional capabilities, whereas the

Japanese rate it on the basis of quality or on the sort of things it makes.

Looking at America, the number of chief executive officers of a company who are technologists can be counted on one's fingers; mostly, they are accountants and lawyers. Japan is about the only country in which technologists are presidents. Look at the engineering firms: the chief executive officers are all engineers at Hitachi, Fujitsu, NEC, Sony, and Honda. Also if such companies as Matsushita and Mitsubishi Heavy Industries are included, almost all of the top officials are technologists.

All of which points to the fact that technology enjoys a high social rating in Japan. This has been the case for over 300 years; it is a traditional way of evaluating technology and the respect that people have for those who make beautiful things.

That is the point of difference between Japan and the United States.

We tend to think that if the Japanese rated science a little higher, the number of people engaging in basic research would increase. If society were to hold basic research in high esteem, great advancements would be made in the field of basic research in Japan. At least, that is the way I see it.

6. Coping with Internationalization

Kato: I am of the opinion that 1986 will be the year in which international matters will have especially great impact. These matters will not be merely a question of arguments or minor developments, but in my opinion this will be the year in which Japan will play a role on the international stage worthy of Japan's place in the world power structure.

In the science and technology arena, criticism from the principal countries of Europe and America that Japan is getting a free ride in basic research is becoming louder. I believe that this is the year in which Japan will take bold action to wipe away such criticism. What do you think?

Yamashita: I think that a bill promoting the intermingled flow of research should be passed as soon as possible. I would like to see foreigners gaining access, even on a small scale, to our research facilities. If such people gain access, we can differentiate between open and closed status facilities, whereas if no access is permitted, we will have to admit that they are closed.

The fruits of research are never translated into English, and as a result, it is said that, "Japan does not publish the fruits of research. On the other hand, results obtained by foreign countries are translated into Japanese regardless of the original language. It is entirely a one-way street."

The strong criticism is understandable. I am of the opinion that the opening up of national research facilities or universities is a most important undertaking. Simultaneously, at the earliest possible time the JICST (Science and Technology Information Center) should start the flow of information in the form of a data base.

Even if other independent and separate project bases are advanced, it will be very difficult to alter the overall impression that has been created. There will be a large impact if there is a flow of foreign personnel given access to the national research facility and if there is a flow of the fruits of research. There is little mass appeal in carrying out specific projects even if they are international in nature.

If foreigners were to have free access to Japan's research facilities, and if the names of foreigners were to appear in a research facility's published papers, it would do wonders for prestige. The joint research structure in Okazaki is open to foreigners, isn't it? I think that Professor Nagakura of Okazaki is doing a very good job with regard to internationalization, but he is almost unknown in Japan. "Why," I often complain to the Ministry of Education, "aren't the people of Japan better informed about that undertaking?" I believe that great changes would be brought about if free access were permitted to the many research facilities existing in Japan. If this were done, it is probable that research facilities in foreign countries would open their doors to people from our national research facilities. If Japan will take the initiative in opening the windows, people from across the seas will probably issue invitations to our research people when they return home.

Kato: We were privileged to hear some very valuable opinions today. We appreciate your giving us some of your precious time. We wish to express our sincere thanks.

New Materials

Tokyo KOGYO GIJUTSU in Japanese Feb 86 pp 5-8

[Discussion with Ken Nagano, president of Japan Mining Industry Association and president of Mitsubishi Metal Corporation conducted by Shoroku Kato, secretariat investigative officer, Ministry of International Trade and Industry]

[Text] Kato: President Nagano of Mitsubishi Metals is currently also the president of the Japan Mining Industry Association, and in those capacities he is working very hard night and day. First of all, standing on the front lines of a technology related corporation as the chief executive officers, he has been responsible for coming up with one innovative technological strategy after another on a continuing basis in the area of entrepreneurial operations. He has also been very active in the research sector and has compiled a very worthy record there.

I am hoping that he will share with us his experience in technological strategies in this high-tech era in which he has participated unstintingly, and also that he will express his opinion on matters pertaining to that area.

Mitsubishi Kinzoku [Mitsubishi Metals] was, until 1973, called Mitsubishi Kinzoku Kogyo [Mitsubishi Metals and Mining]. We assume that the name was changed in consonance with Japan's rapidly changing industrial structure and technological reformation. Many innovative changes were undoubtedly made within the company, and changing the name was indicative of such changes.

We would appreciate your sharing with us the efforts that were made within the firm in the context of technology to keep in step with environmental changes in Japan.

Nagano: I am embarrassed by your words of praise. I don't think that whatever was done was undertaken with such high regard for idealism. Judging by results, however, we seem to have been more innovative than others in the same line of endeavor, and our basic principles may have been broader than those of others.

Work on powdered forged metal and the manufacture of very hard materials and molten materials were started before the war, and today they are the mainstays of our income.

Basically, we are a mining company. This has been broadened to mines, refineries, fabrication, nuclear power, electronic materials and new materials. Our mines typify the raw materials industry. Currently there is a worldwide slump in demand for copper, lead, zinc and other nonferrous metals, and they command a low price on the international market, putting the mining industry in a very sad state.

On the other hand, we frequently hear the term "new raw materials," Traditionally, raw materials were categorized as commodities. The object was to produce high-quality commodities in large quantity and at low price, then place them on the market to be sold in unspecified large quantities by which deals could be made.

With new materials, for example, by radically raising the purity rating of copper, very thin wire as fine as 10 microns can be produced. Production of such fine lines was not possible with old materials, but now it can be done, so this item can clearly be defined as a "new raw material."

In the area of copper alloys, such items as shaped memory alloys have been produced. That is, properties that were not attributes of a given substance have been brought out by fabrication. And the application of a specific process has made a new raw material out of an old raw material. An example of this is that when a metal is ground up into a very fine powder, new characteristics appear. There is also an example of new properties becoming attributes of a metal when it is converted into very miniscule fibers.

It is also likely that substances commonly called rare metals and rare earths will gain more and more attention in electronics and other leading-edge sectors in the future.

I believe that the entry of companies like our into those two areas is a good idea. Such metal is oxydized or exposed to nitrides or combined with other organic materials. When items that satisfy a need are produced through such processes, we proceed with the work and designate such items as "new raw materials." There would be little growth in demand if the material were left in its old form but by allowing the processing flow to take the material downstream, there may be demand for them. I believe that that is what is actually happening at the present time.

Kato: The development of new raw materials and the fields in which they can be used is what your firm calls the "Star plan" is it not?

Nagano: To take such material and definitively program it by specifying what will be accomplished by what year and predict that total sales will be at such and such level is what we call the "Star plan." Then, if we are to determine where the focal point lies, the research facility is the seedbed and the items that are germinated and grown there are used for actual production.

Kato: One sector is that of new raw materials, and another is that of nuclear fuel for the conversion of atomic energy for use in electronics. What is the background for interfacing these sectors?

Nagano: We first conceived of entering the field of atomic energy in 1965, when the peaceful use of nuclear energy was proposed. All knowledge pertaining to this had been out of bounds until then.

Because we were a mining company, we decided that we would operate uranium mines if we could, and that we would make fuel from this and dispose of the waste resulting from these processes. We considered that this concept--the so-called nuclear fuel cycle--was the proper path for a company engaged in such such work to follow.

As to the other sector, electronics, our company was the first to produce germanium for use in semiconductors in the decade following 1945.

In 1959-1960, we also broke into the silicon sector. The changeover from germanium to silicon for semiconductors was a very logical step for Japan and an exceedingly fortunate one for our company. This is because silicon is the most plentiful element in the earth's crust.

I believe that with this wealth of raw material, regardless of what new form of semiconductors may appear, if silicon can be used, it will be used. That is why we have created a variety of IC peripherals with silicon as their nuclei.

Kato: You have successfully penetrated the fields of nuclear energy, new materials, and electronics one after another. A very solid technological foundation was required prior to entering those fields. It seems apparent that your company was always a step ahead.

Nagano: Well, yes. In the old days we seemed to jump at anything new. We hopped on germanium at first blossom.

Kato: Your company used to support a mining research facility. The fruits of research and development conducted there must have been transferred to the central research facilities at an early stage. The current developmental process must be derived from the findings stored there.

Nagano: That's more or less it. We are still carrying on some interesting research and development programs. The low-cost production of diamonds, for example.

Kato: I hear that for personnel education purposes leading to early development of new areas, young technologists are put into the central research facilities for 3 years.

Nagano: Yes. A young technologist is placed in the central research facilities for 3 years after he has been assigned one new category of endeavor; he is given an opportunity to pursue studies in physics, chemistry, electricity and other categories that are not his specialty. He prepares himself for the time when outside knowledge will be essential to carrying on in his specialized field. The process puts him in touch with persons in other new fields of endeavor and leads them to be able to talk to each other in the same language at least.

Kato: When was this program begun?

Nagano: It willbe 2 years this year. Graduates will begin to come out beginning next year. We are anticipating that with a great deal of pleasure.

Twenty-five graduates with a new sense of things will emerge from the research facilities every year. We are looking forward to that.

Kato: They will form a continuous stream of people with high potential.

Nagano: Yes. And because we have so much overseas work, we are dispatching four or five persons to foreign countries every year on about the same schedule.

Kato: From now on, relations with foreign countries should become increasingly important. Recently, one has heard the criticism from various foreign countries that Japan is getting a free ride on new technologies and that the Japanese lack creativity or originality. Although I do not think all of these criticisms are justified, some of them are. Thus, in the future I believe that more emphasis should be placed on originality in our technology in order to make contributions to the world in the area of technology. I get the impression that in your company the spirit of innovative research and development bubbles up naturally. Is there some secret that brings this about?

Nagano: Reviewing the situation, let me put aside the complex problem of creative orginality. If self-confidence can be instilled in the researcher, he will look forward to undertaking problems without qualms that otherwise he would have considered too difficult.

To assign simple tasks at first as a confidence builder is an educational step in this growth process of a person. Our secret is that we were successful in this educational program.

Kato: I think that giving confidence is an important step. I believe that the instances in which Japan will have an opportunity to extend a helping hand in the research sector to European and American countries will increase. In those instances, Japan must be prepared to depart from logic and put aside thoughts of material profit to offer full cooperation.

Nagano: That is so. Of particular concern are the language and cultural differences and the differences in concept innovation.

Kato: From the standpoint of advancing innovative research and development undertakings, there are many national projects. Recently, however, because of tightening national finances, there seems to be much talk of utilization of private activity, even in the so-called national projects. A great deal of discussion is being conducted on how to utilize private activity in the area of national research and development. A Basic Technology Research Promotion Center has been established. How do you, as a private entrepreneur, see the concept of utilizing private sector participation?

Nagano: The Basic Technology Research Promotion Center is a national project to stimulate private participation. Separately, ceramics, space, and other groups are being established. Our company is also very interested in this trend and has been permitted to participate in all of the fields.

However, much of this is till only in the "idea" stage, and only a few small portions have actually been activated. For this reason, we are in no position to report on how successful it is. We do consider that all kinds of possibilities are being offered to us.

Kato: The environment in Japan will undoubtedly become even more severe in 1986; I believe there will be some drastic problems in the economic as well as the technological areas. In face of this, what are your company's programs, particularly in the technological area, for 1986?

Nagano: We believe that the electronics-related field will make a comeback in 1986, and we are convinced that we will have to be technologically perfect. Currently, we are making every effort to enable the achievement of this goal. In the atomic energy field, as you know, the nuclear fuel project at Shimoketa is beginning to move, and this will require complete attention. Because the automotive industry is still doing well, we assume that our parts-related business will be extremely active.

Kato: Changing the subject, I am of the opinion that the technological reformation will continue for the foreseeable future in electronics, information, and bionics new materials. When we enter the 21st century, various new areas will open up, causing major changes in the social and industrial structures. What forecasts and visions does your company have for the 21st century?

Nagano: Rather than new technologies, I believe that the methods of making an item will undergo changes. It is often said that we are proceeding into the "age of local districts." As a trend, labor will become decentralized to outlying districts. That will mean that instead of big industries building big plants in urban areas and drawing on a concentration of labor from the outlying areas, the process will be reversed. Each work project that can be isolated will be undertaken in small factories in small communities. If, for example, community is capable of supplying 50 laborers, a plant suited to that number will be built. This will eliminate the wasteful employee commuter time, giving the worker all of the nonworking hours to himself. Utilizing

the information system to the fullest, control functions such as administration and accounting will be centralized for economy of work. I am convinced that the number of factories operating on the basis of this concept will increase. Such a factory that is closely related to the local area will facilitate tapping the labor pool; because plant operation will be closely related to the environment and the individual's living standard, the locality, the company and the employee will all benefit. If this happens, Mitsubishi Metals will be composed of 50 or 60 small plants in the 21st century. We look forward to this with pleasure; the localities will also prosper.

Kato: We feel very privileged to have had the opportunity to hear so many interesting and instructional views and to have received so much of your time. We thank you very much.

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SURVEY LOOKS AT RECENT TRENDS IN RESEARCH, DEVELOPMENT

Tokyo KOGYO GIJUTSU in Japanese Feb 86 pp 20-30

[Technology survey by the Kogyo Gijutsu Management Division, Jan 86]

[Text] In December 1985 the Management and Coordination Agency published a survey of scientific technology research (a spot report), which revealed the condition of research related to scientific technology in Japan. Every year since 1953, on 1 April (for financial affairs a year retrospective to the most recent day prior to 1 April when accounts were settled) this has been reported in order to provide the necessary fundamental data to promote scientific technology.

The 1985 survey included approximately 12,100 companies, 1,300 research organs, and 2,000 universities.

What follows is a summary of the results of the Management and Coordination Agency's survey of research activity related to scientific technology. Data for which no specific source is listed were obtained from the Management and Coordination Agency's survey.

I. Research Expenditures

(1) Total research expenditures. Total research expenditures amounted to ¥7.8939 trillion, a 9.9 percent increase over the last fiscal year. Total research expenditures for Japan in fiscal year 1984 amounted to ¥7.839 trillion, a rise of 9.9 percent or ¥713.3 billion over fiscal year 1983's ¥7.1808 trillion total. There has been a nominal increase of 2.9 times or a real increase of 1.8 times in the 10 years since fiscal year 1974.

Research expenditures in the natural sciences exceeded ¥7 trillion. Research expenditures in the natural sciences came to ¥7.1765 trillion, which is an increase of ¥672.8 billion, a nominal increase of 10.3 percent, and a real increase of 7.5 percent over fiscal year 1983.

Research expenditures in the natural sciences amounted to 90.9 percent of total research expenditures. This percentage has gradually increased from a low of 88.2 percent in fiscal year 1978. In fiscal year 1982 the 90 percent mark was reached and by fiscal year 1984 it had become 90.9 percent. (Table 1).

Steadily rising total research expenditures compared with GNP. Total scientific technology research expenditures were 2.60 percent of GNP.

Viewed over the last 10 years, this percentage shifted around the 1.9 percent mark until fiscal year 1978. Then in fiscal year 1979 the figure became 2.03 percent, reaching the 2 percent mark for the first time. Thereafter, the percentage rose from 2.14 percent in fiscal year 1980 to 2.30 percent in fiscal year 1981, to 2.40 percent in fiscal year 1982, to 2.53 percent, in fiscal year 1983, and to 2.60 percent in fiscal year 1984. Japan's total scientific technology research expenditures as a percentage of GNP have steadily risen.

(1) 表1 (5)研究費の推移

(2) 年度	(3) 研究費 (億円)			(4) 対前年度増加率(%)		(5) 実質研究費 (億円)		(6) 対前年度増加率(%)		(7) デフレーター (55年度=100)		(8) 対GNP比率 (%)
	(9) 総額	(10) 自然科学部門	(11) 割合(%)	(9) 総額	(10) 自然科学部門	(9) 総額	(10) 自然科学部門	(9) 総額	(10) 自然科学部門	(9) 総額	(10) 自然科学部門	
49	27 160	24 214	89.2	22.6	22.2	39 738	35 194	−1.3	−1.6	68.3	68.8	1.97
50	29 746	26 218	88.1	9.5	8.3	40 451	35 478	1.8	0.8	73.5	73.9	1.95
51	33 207	29 414	88.6	11.6	12.2	41 556	36 721	2.7	3.5	79.9	80.1	1.94
52	36 513	32 335	88.6	10.0	9.9	43 410	38 449	4.5	4.7	84.1	84.1	1.92
53	40 459	35 700	88.2	10.8	10.4	46 720	41 319	7.6	7.5	86.6	86.4	1.94
54	45 836	40 636	88.7	13.3	13.8	49 277	43 695	5.5	5.8	93.0	93.0	2.03
55	52 462	46 838	89.3	14.5	15.3	52 462	46 838	6.5	7.2	100.0	100.0	2.14
56	59 824	53 640	89.7	14.0	14.5	57 715	51 826	10.0	10.7	103.7	103.5	2.30
57	65 287	58 815	90.1	9.1	9.6	61 069	55 122	5.8	6.4	106.9	106.7	2.40
58	71 808	65 037	90.6	10.0	10.6	66 155	60 053	8.3	8.9	108.5	108.3	2.53
59	78 939	71 765	90.9	9.9	10.3	70 752	64 537	6.9	7.5	111.6	111.2	2.60

(12) 注) 実質化に当たり，デフレーターの算出は，研究費に占める人件費，原材料費などの費目等に価格指数を求め，それに基準年次（昭和55年度=100）のウエイトを乗じて合算する方法による。

Key:

1. Table 1. Changes in Research Expenditures
2. Fiscal year
   - 49 - 1974
   - 50 - 1975
   - 51 - 1976
   - 52 - 1977
   - 53 - 1978
   - 54 - 1979
   - 55 - 1980
   - 56 - 1981
   - 57 - 1982
   - 58 - 1983
   - 59 - 1984
3. Research expenditures (¥ 100 million)
4. Rate of increase over previous year
5. Real research expenditures (¥ 100 million)
6. Rate of increase over previous fiscal year (%)
7. Deflator (1980 = 100)
8. Percentage of GNP (%)
9. Total
10. Natural sciences
11. % of total
12. Caution: for conversion to real expenditures the deflator is computed by establishing an index for the value of labor costs, material costs, etc., which are included in research expenditures and this is multiplied by the base year (fiscal year 1980 = 100)

Table 2. Research Expenditures of Key Countries Compared With GNP

Country		Total research expenditures (¥ 100 million)	Comparison with GNP (%)
Japan	1984 (fiscal year)	78,939	2.60
United States	1984 (year)	230,316	2.65
England	1981 (fiscal year)	26,479	2.34
West Germany	1983 (fiscal year)	43,515	2.80
France	1983 (fiscal year)	26,432	(1982) 2.80
Soviet Union	1983 (fiscal year)	80,630	(1982) 3.78

Data: Excepting Japan, the Science and Technology Agency's "1985 Science and Technology White Paper"
Note: England is natural sciences only.

(2) Research expenditures by companies exceeded ¥5 trillion. (Separate classification of research bodies.) Looking at total research expenditures in fiscal year 1984 by type of research body, companies spent ¥5.1366 trillion, research institutions spent ¥1.331 trillion, and universities spent ¥1.7242 trillion. This was the first time that companies exceeded the ¥5 trillion mark and that universities exceeded the ¥1 trillion mark.

Compared with the previous fiscal year, companies experienced a rise of 12.6 percent. This healthy rise was a continuation from the previous fiscal year (with a 12.9 percent increase). Research institutions and universities experienced smaller increases of 6.4 percent and 4.5 percent, respectively.

As a percentage of total research expenditures, companies increased from the previous fiscal year's 63.5 percent to 65.1 percent while research institutions declined from 13.5 percent to 13.1 percent and universities declined from 23.0 percent to 21.8 percent. (Table 3)

(3) There has been a continued increase in research expenditures by private bodies (classification of research expenditures by separate bodies). Total research expenditures for fiscal year 1984 were divided by national and regional public bodies and private bodies. National and regional public bodies spent ¥1.7778 trillion and private bodies spent ¥6.1086 trillion. National and regional public bodies had a limited 3.3 percent increase over the previous fiscal year while private bodies had a healthy 12.1 percent increase.

(1) 表3 研究主体別研究費の推移

(2) 区	分	(3) 総額	(4) 会社等	(5) 研究機関	(6) 大学等
(7) 実額（億円）	(10) 年度 49	27,160	15,891	4,094	7,176
	54	45,836	26,649	6,604	12,583
	55	52,462	31,423	7,639	13,401
	56	59,824	36,298	9,069	14,456
	57	65,287	40,390	9,493	15,404
	58	71,808	45,601	9,710	16,496
	59	78,939	51,366	10,331	17,242
(8) 対前年度増加率（%）	(10) 年度 49	22.6	22.1	20.5	25.0
	54	13.3	16.3	9.4	9.3
	55	14.5	17.9	15.7	6.5
	56	14.0	15.5	18.7	7.9
	57	9.1	11.3	4.7	6.6
	58	10.0	12.9	2.3	7.1
	59	9.9	12.6	6.4	4.5
(9) 構成比（%）	(10) 年度 49	100.0	58.5	15.1	26.4
	54	100.0	58.1	14.4	27.5
	55	100.0	59.9	14.6	25.5
	56	100.0	60.7	15.2	24.2
	57	100.0	61.9	14.5	23.6
	58	100.0	63.5	13.5	23.0
	59	100.0	65.1	13.1	21.8

Key:

1. Table 3. Changes in Research Expenditures by Different Research Bodies
2. Classification
3. Total
4. Companies
5. Research institutions
6. Universities
7. Real expenditures (¥100 million)
8. Rate of increase over previous year (%)
9. Comparative make-up (%)
10. Fiscal year
    - 49 - 1974
    - 54 - 1979
    - 55 - 1980
    - 56 - 1981
    - 57 - 1982
    - 58 - 1983
    - 59 - 1984

As a result, national and regional public bodies' expenditures decreased from 24.0 to 22.5 percent of total research expenditures while private bodies' expenditures increased from 75.9 percent to 77.4 percent. This proportion has continued to rise for private bodies since 1979. Compared with national and regional bodies, research activity in private bodies is relatively active. (Table 4)

(4) The percentage of expenditures in basic and applied research has had a minor decline while the percentage of expenditures in developmental research has had a minor increase. In the natural sciences (basic, applied, and developmental) ¥7.809 trillion was spent on research; basic research expenditures amounted to 13.6 percent, applied research expenditures were 25.1 percent, and developmental research was 61.3 percent.

(1)表4 国・地方公共団体，民間の支出別研究費の推移

(2)年度	(3)研究費 (億円)				(4)支出割合 (%)		(5)対前年度比増加率 (%)	
	(6)総額	(7)国・地	(8)民間	(9)外国	(10)国・地	(11)民間	(12)国・地	(13)民間
49	27,160	7,832	19,312	16	28.8	71.1	25.1	21.6
54	45,836	13,534	32,266	36	29.5	70.4	11.0	14.3
55	52,462	14,650	37,763	49	27.9	72.0	8.2	17.0
56	59,824	16,124	43,638	61	27.0	72.9	10.1	15.6
57	65,287	16,662	48,555	70	25.5	74.4	3.3	11.3
58	71,808	17,214	54,511	82	24.0	75.9	3.3	12.3
59	78,939	17,778	61,086	76	22.5	77.4	3.3	12.1

(14)注) 国・地は，国・地方公共団体を表す。

Key:

1. Table 4. Changes in Research Expenditures by National and Regional Public Bodies and Private Bodies
2. Fiscal year
   - 49 - 1974
   - 54 - 1979
   - 55 - 1980
   - 56 - 1981
   - 57 - 1982
   - 58 - 1983
   - 59 - 1984
3. Research expenditures (¥100 million)
4. Percentage of expenditures (%)
5. Rate of increase over previous year (%)
6. Total
7. National and regional
8. Private
9. Foreign
10. National and regional
11. Private
12. National and regional
13. Private
14. Note: National and regional stands for national and regional public bodies

Compared with the previous fiscal year, research expenditures by universities with a high proportion of research in basic science rose only slightly while research expenditures by companies with a high proportion of research in developmental science experienced a significant rise. Overall basic research expenditures rose by a slight 0.4 percent, applied research expenditures by a small 0.3 percent, and developmental research expenditures rose by a large 0.7 percent. (Table 5)

(5) Electrical equipment industries accounted for one-third of research expenditures by companies. In fiscal year 1984 the largest research expenditures by companies were made by the manufacturing industry with ¥4.7765 trillion which accounted for 93 percent of all industry; this was followed by the transportation, communication, and public service industry with ¥220.5 billion, the construction industry with ¥116.1 billion, the mining industry with ¥18.8 billion, and the agriculture, forestry and fishery industry with ¥4.8 billion.

The rate of increase over the previous fiscal year was the highest for the transportation, communication, and public service industry with an increase of 22.3 percent, followed by the mining industry with a 20.2 percent increase, construction with a 14.6 percent increase, manufacturing with a 12.2 percent increase, and the agriculture, forestry and fishery industry with a decrease of 15.5 percent.

When main divisions of the manufacturing industry are looked at, the electrical machine industry accounts for one-third of company research expenditures with ¥1.6345 trillion, next is the chemical industry with ¥852.8 billion, and the shipping industry with ¥808.2 billion. Other industries with research expenditures of over ¥100 billion are the machine industry with ¥337.5 billion, the iron-and-steel industry with ¥192.1 billion, the precision machine industry with ¥167.4 billion, the ceramic industry with ¥131.3 billion, and the food industry with ¥123.7 billion. The rate of increase over the previous fiscal year for these industries showed a solid rise of over 10 percent beginning with a 15.9 percent increase for the ceramic industry, a 15.4 percent increase for the electrical machine industry, a 13.1 percent increase for the shipping industry, and an 11.3 percent increase for the food industry, and 10.1 percent for the chemical industry. However, the machine industry (8.3 percent rise), the precision machine industry (5.4 percent rise) and the iron-and-steel industry (3.2 percent rise) had but limited growth. (Table 6, Diagram 1)

If developmental research expenditures are looked at at the enterprise level, this trend can be proved. There is data for enterprises in the Toyo Keizai Co's "Four Season Company Report" (Table 7) and in The Nihon Keizai Shimbun Inc's "Nikkei Company Report." (Table 8)

(1) 表5　自然科学の研究主体，性格別研究費

(2) 区分		総額 (3)	基礎研究費 (4)	応用研究費 (5)	開発研究費 (6)
(7) 研究費（億円）	年度 (8)				
	54	39,511	6,114	10,220	23,177
	55	45,384	6,598	11,534	27,252
	56	52,067	7,243	13,400	31,424
	57	57,950	8,157	14,989	34,805
	58	64,096	8,967	16,301	38,828
	59	70,809	9,599	17,808	43,402
	(9) 会社等	51,366	2,900	11,286	37,180
	(10) 研究機関	9,512	1,245	2,892	5,375
	(11) 大学等	9,931	5,454	3,630	847
(12) 対前年度増加率（%）	年度 (8)				
	58	10.6	9.9	8.8	11.6
	59	10.5	7.1	9.2	11.8
	(9) 会社等	12.6	11.6	12.7	12.7
	(10) 研究機関	6.4	10.7	4.6	6.5
	(11) 大学等	3.9	4.0	3.0	7.3
(13) 構成比（%）	年度 (8)				
	54	100.0	15.5	25.9	58.7
	55	100.0	14.5	25.4	60.0
	56	100.0	13.9	25.7	60.4
	57	100.0	14.1	25.9	60.1
	58	100.0	14.0	25.4	60.6
	59	100.0	13.6	25.1	61.3
	(9) 会社等	100.0	5.6	22.0	72.4
	(10) 研究機関	100.0	13.1	30.4	56.5
	(11) 大学等	100.0	54.9	36.6	8.5

Key:

1. Table 5. Research Expenditures by Type of Research Bodies in the Natural Sciences
2. Classification
3. Total
4. Basic research expenditures
5. Applied research expenditures
6. Developmental research expenditures
7. Research expenditures (¥100 million)
8. Fiscal year
   - 54 - 1979
   - 55 - 1980
   - 56 - 1981
   - 57 - 1982
   - 58 - 1983
   - 59 - 1984
9. Companies
10. Research institutions
11. Universities
12. Rate of increase over previous year (%)
13. Composition (%)

Table 7 ranks the payments made by 30 Japanese enterprises with the highest development research expenditures. According to this there are 12 companies involved in the electronics industry (Hitachi Ltd., Matsushita Ltd., Nippon Electric Industry Co., Ltd., Toshiba Corp., Fujitsu Ltd., Mitsubishi Electric Corp., Sony Corp., Sharp Corp., Victor Co. of Japan, Ltd., Matsushita Communication Industrial Co., Ltd., Sanyo Electric Co., Ltd and Oki Electric Industry Co., Ltd. Then there are 5 companies related to the chemical industry (Fuji Photo Film Co., Ltd., Takeda Chemical Industries, Ltd., Bridgestone Corp., Sumitomo Chemical Co., Ltd., and Mitsubishi Chemical Industries, Ltd.). Four companies in the automobile industry (Toyota Motor Corp., Nissan Motor Co., Ltd., Honda Motor Co., Ltd., and Mazda Motor Corp.) and 4 companies in the steel industry (Nippon Steel Corp., Sumitomo Metal

(1) 表 6　産業別研究費（59年度）

(2) 産業	(3) 研究費（億円）	(4) 対前年度増加率（%）	(5) 構成比（%）
(6) 全産業	51,366	12.6	100.0
	(44,495)	(16.1)	(86.6)
(7) 農林水産業	48	−15.5	0.1
(8) 鉱業	188	20.2	0.4
(9) 建設業	1,161	14.6	2.3
(10) 製造業	47,765	12.2	93.0
(11) 食品工業	1,237	11.3	2.4
(12) 繊維工業	595	16.6	1.2
(13) パルプ・紙工業	291	13.3	0.6
(14) 出版・印刷業	139	20.6	0.3
(15) 化学工業	8,528	10.1	16.6
(16) 総合化学・化学繊維工業	3,463	16.3	6.7
(17) 油脂・塗料工業	843	12.4	1.6
(18) 医薬品工業	2,953	1.9	5.7
(19) その他の化学工業	1,270	13.4	2.5
(20) 石油製品・石炭製品工業	560	12.3	1.1
(21) プラスチック製品工業	640	23.5	1.2
(22) ゴム製品工業	684	18.4	1.3
(23) 窯業	1,313	15.9	2.6
(24) 鉄鋼業	1,921	3.2	3.7
(25) 非鉄金属工業	877	18.5	1.7
(26) 金属製品工業	835	0.8	1.6
(27) 機械工業	3,375	8.3	6.6
(28) 電気機械工業	16,345	15.4	31.8
(29) 電気機械器具工業	5,382	17.6	10.5
(30) 通信・電子・電気計測器工業	10,964	14.4	21.3
(31) 輸送用機械工業	8,082	13.1	15.7
(32) 自動車工業	6,867	13.3	13.4
(33) その他の輸送用機械工業	1,215	11.8	2.4
(34) 精密機械工業	1,674	5.4	3.3
(35) その他の工業	670	0.9	1.3
(36) 運輸・通信・公益業	2,205	22.3	4.3

(37) 注）（　）内は，資本金10億円以上の会社等。

Key:

1. Table 6. Production Expenditures (fiscal year 1984)
2. Industry
3. Research expenditures (¥ 100 million)
4. Rate of increase over previous year (%)
5. Composition (%)
6. All industries
7. Agriculture, forestry and fishery industry
8. Mining industry
9. Construction industry
10. Manufacturing industry
11. Food industry
12. Textile industry
13. Pulp and paper industry
14. Publishing and printing industry
15. Chemical industry
16. Synthetic chemical and fiber industry
17. Oil, fat and paint industry
18. Pharmaceutical industry
19. Other chemical industries
20. Petroleum and coal industry
21. Plastic products industry
22. Rubber products industry

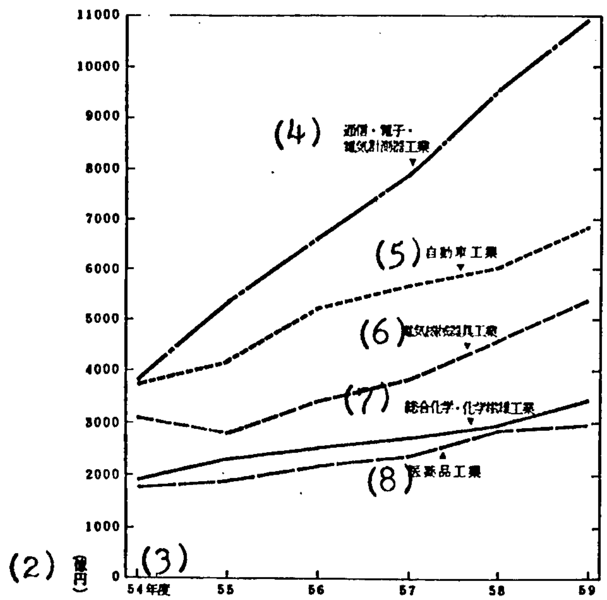
[key continued on following page]

23. Ceramic industry
24. Iron-and-steel industry
25. Nonferrous metals industry
26. Metal products industry
27. Machine industry
28. Electrical machine industry
29. Electrical appliance industry
30. Communications, electronics, and electrical measuring instruments industry
31. Shipping industry
32. Automobile industry
33. Other transportation industries
34. Precision machine industry
35. Other industries
36. Transportation, communication, and public service industry
37. Note: ( ) indicate companies with capital of over ¥ 1 billion

Industries, Ltd., Nippon Kokan K.K., and Kawasaki Steel Corp.). In addition there are 2 companies in heavy industry (Mitsubishi Heavy Industries, Ltd., and Ishikawajima-Harima Heavy Industries Co., Ltd.) and in the precision machine industry (Canon Inc. and Ricoh Co., Ltd.) and there is also The Tokyo Electric Power Co., Ltd. It is apparent that the classification of these large companies basically corresponds with the macro classification of the Management and Coordination Agency's survey. Furthermore, if growth in developmental research expenditures is looked at for individual enterprises, the growth of several tens of percentage points in the electronics industry can be substantiated.

Table 8 ranks Japanese enterprises on the basis of a comparison between developmental research expenditures and top sales. In this table research expenditures are based on estimates of fiscal year 1985 and actual results for fiscal year 1984. The lead held by large companies of the Toshiba, Ltd., and Fujutsu, Ltd. class is apparent and continued growth in fiscal year 1985 in the electronics, automobile, and chemical industries is shown.

Table 9 summarizes research expenditures of large enterprises in the United States from a special issue, "Scoreboard Special" from a BUSINESS WEEK from last year. It appears that there is a gap between the subjects of the studies since the top United States enterprise, General Motors, spent \$2.6 billion or almost 3 times as much as was spent by the top Japanese enterprise, Hitachi, Ltd. However, Hitachi Ltd. which spent ¥221 billion can be ranked with the number four United States company, United Technology, which spent \$970 million.



(1) 図1　製造業の主な産業別研究費の推移

Key:

1. Diagram 1. Change in Research Expenditures for Key Manufacturing Industries
2. ¥100 million
3. Fiscal year
   54 - 1979
   55 - 1980
   56 - 1981
   57 - 1982
   58 - 1983
   59 - 1984
4. Communications, electronics, and electrical instrumentation industries
5. Automobile industry
6. Electrical appliance industry
7. Synthetic chemical and fiber industry
8. Pharmaceutical industry

(1) 表7　研究開発費上位30社（59年度）(2) （単位：億円）

(3) 社名	(4) 研究開発費（前年度比増加率%）	(5) 設備投資費
(6) 日立製作所	2,192(18)	2,000
(7) ☆松下電器産業	2,000(15)	580
(8) 日本電気	1,900(19)	2,100
(9) トヨタ自動車	1,900(9)	2,100
(10) 東芝	1,550(24)	1,890
(11) 日産自動車	1,500(7)	1,400
(12) 富士通	1,280(29)	2,060
(13) 本田技研工業	1,068(8)	800
(14) 三菱電機	950(14)	950
(15) ソニー	900(9)	700
(16) マツダ	750(23)	800
(17) 三菱重工業	700(3)	500
(18) シャープ	512(24)	811
(19) 新日本製鉄	500(0)	1,860
(20) キヤノン	400(37)	500
(21) 富士写真フイルム	360(0)	480
(22) 東京電力	350(25)	10,901
(23) 武田薬品工業	305(6)	180
(24) リコー	280(27)	400
(25) 日本ビクター	260(18)	400
(26) 松下通信工業	250(15)	100
(27) ブリヂストン	245(7)	400
(28) 住友金属工業	240(0)	800
(29) 日本鋼管	230(5)	1,028
(30) 住友化学工業	230(5)	260
(31) 川崎製鉄	230(3)	1,230
(32) 三洋電機	215(16)	400
(33) 沖電気工業	210(36)	555
(34) 三菱化成工業	200(▲15)	300
(35) 石川島播磨重工業	200(0)	120

(36) 出典：東洋経済「会社四季報」☆印は連結ベース

Key:

1. Table 7. Top 30 Companies for Developmental Research Expenditures
2. Unit: ¥ 100 million
3. Company name
4. Developmental research expenditures (rate of increase over previous year)
5. Investment in equipment
6. Hitachi, Ltd.
7. Matsushita Electric Industrial Co., Ltd.
8. Nippon Electric Industry Co., Ltd.
9. Toyota Motor Corp.
10. Toshiba Corp.
11. Nissan Motor Co., Ltd.
12. Fujitsu Ltd.
13. Honda Motor Co., Ltd.
14. Mitsubishi Electric Corp.
15. Sony Corp.
16. Mazda Motor Corp.
17. Mitsubishi Heavy Industries, Ltd.
18. Sharp Corp.
19. Nippon Steel Corp.

20. Canon Inc.
21. Fuji Photo Film Co., Ltd.
22. The Tokyo Electric Power Co., Ltd.
23. Takeda Chemical Industries, Ltd.
24. Ricoh Co., Ltd.
25. Victor Co. of Japan, Ltd.
26. Matsushita Communication Industrial Co., Ltd.
27. Bridgestone Tire Co., Ltd.
28. Sumitomo Metal Industries, Ltd.
29. Nippon Kokan K.K.
30. Sumitomo Chemical Co., Ltd.
31. Kawasaki Steel Corp.
32. Sanyo Electric Co., Ltd.
33. Oki Electric Industry Co., Ltd.
34. Mitsubishi Chemical Industries, Ltd.
35. Ishikawajima-Harima Heavy Industries Co., Ltd.
36. Source: Toyo Keizai "Four Seasons Company Report"
☆ indicates the connection base

II. Researchers

(1) The number of individuals engaged in research related work is 762,800; growth was the lowest in 5 years. As of 1 April 1985 (referred to as "1985" below) the number of individuals involved in research related work was 762,800, an increase of 21,500 people or 2.9 percent over last year, which is the lowest growth rate in the last 5 years.

Looking at the number of individuals in research related work by classification, there were 672,900 individuals in the natural sciences and 50,100 in the humanities and social sciences. Compared with last year the number of individuals in the natural sciences grew by 20,400 individuals or 3.1 percent while the increase in the humanities and social sciences was 900 individuals, a 1.8 percent rise. In 1985 researchers in the natural sciences accounted for 88.2 percent of those involved in research related work and this percentage has been increasing yearly. (Table 10)

(2) Companies account for the majority of individuals engaged in research related work. In 1985 the number of individuals in different research bodies engaged in research-related work was 427,600 individuals in companies (56.1 percent of the number engaged in research-related work), which is more than half for all research bodies. Next were universities with 247,600 individuals (32.5 percent) and research institutions with 87,600 individuals (11.5 percent).

The rate of increase over the previous year for individuals engaged in research-related work in the different groups was 3.7 percent for companies, which exceeded the total rate of increase (2.9 percent), while research institutions and universities together rose 1.9 percent, which fell short of the total rate of increase. (Table 11)

Table 8. Ranking of Percentage of Proceeds Spent in Developmental Research (Subject of investigation: "Survey of Developmental Research Expenditures," approximately 750 companies replied)

Ranking	Company name	Proceeds spent in developmental research in fiscal year 1985 (percent)	1985 developmental research expenditures (¥1 million)	1984 developmental research expenditures (¥1 million)
1	Denyo	16.36	(450)	411
2	Fujirebio Inc.	13.19	(2,244)	1,747
3	Yoshitomi Pharmaceutical Industries, Ltd.	12.52	(7,700)	7,789
4	Eisai Co., Ltd.	12.46	(17,200)	16,282
5	Kaken Pharmaceutical Co., Ltd.	11.76	(4,000)	4,019
6	Fujisawa Pharmaceutical Co., Ltd.	11.49	(20,000)	18,722
7	Nippon Electric Industry Co., Ltd.	11.21	(230,000)	200,000
8	Nippon Shinyaku Co., Ltd.	11.11	(4,500)	4,336
9	Horiba Ltd.	10.85	(1,900)	1,460
10	Daiichi Seiyaku Co., Ltd.	10.78	(11,200)	9,996
11	Ono Pharmaceutical Co., Ltd.	10.53	(4,900)	3,418
12	Chugai Pharmaceutical Co., Ltd.	10.43	(10,800)	9,774
13	Yamanouchi Pharmaceutical Co., Ltd.	10.00	(11,500)	10,732
13	Toyama Chemical Co., Ltd.	10.00	(4,000)	3,515
15	Banyu Pharmaceutical Co., Ltd.	9.67	(6,000)	5,200
16	Olympus Optical Co., Ltd.	9.33	(12,000)	10,318
17	Shionogi & Co., Ltd.	9.17	(17,890)	15,977
18	Dainippon Pharmaceutical Co., Ltd.	9.11	(6,225)	6,102
19	Canon Inc.	8.96	(52,000)	40,973
20	Kureha Chemical Industry Co., Ltd.	8.60	(10,500)	8,700
21	Nihon Kagaku Sangyo Co., Ltd.	8.57	(8,804)	8,734
22	Nakamichi Kikai Co., Ltd.	8.41	(900)	582
23	Santen Pharmaceutical Co., Ltd.	8.35	(1,472)	1,446
24	Jeco Co., Ltd.	8.33	(1,500)	1,257
25	Hitachi, Ltd.	8.25	(247,600)	221,100
26	Tokyo Tanabe Co., Ltd.	8.09	(2,000)	1,802
27	Tanabe Seiyaku Co., Ltd.	7.77	(11,537)	10,669
28	Glory Ltd.	7.71	(3,280)	2,953
29	Nippon Electric Co., Ltd.	7.67	(3,916)	3,494
30	Iwasaki Tsushinki	7.50	(6,300)	5,600
31	Kyowa Electronic Instruments Co., Ltd.	7.40	(1,000)	900
32	Tokushu Togyo Co., Ltd.	6.70	(5,500)	5,324
33	Taisho Pharmaceutical Co., Ltd.	6.69	(7,670)	7,098
34	Takeda Chemical Industries, Ltd.	6.63	(31,500)	30,453
35	Ricoh Co., Ltd.	6.60	(34,000)	28,643
36	Furuno Electric Co., Ltd.	6.58	(2,700)	2,508
37	Ishihara Sangyo Kaisha Ltd.	6.56	(4,400)	4,103

[continued]

[Continuation of Table 8]

Ranking	Company name	Proceeds spent in developmental research in fiscal year 1985 (percent)	1985 developmental research expenditures (¥1 million)	1984 developmental research expenditures (¥1 million)
38	Sankyo Co., Ltd.	6.47	(16,500)	15,955
39	Matsushita, Ltd.	6.37	(220,000)	200,117
40	Tokyo Seimitsu Co., Ltd.	6.33	(1,300)	906
41	Fuji Photo Film Co., Ltd.	6.25	(40,000)	37,761
42	Nippon Soda Co., Ltd.	6.24	(5,400)	5,134
43	Ono Sokki Co., Ltd.	6.15	(800)	733
44	Sharp Corp.	6.12	(60,000)	49,974
45	Nikken Chemicals Co., Ltd.	6.10	(2,016)	1,740
46	Anritsu Electric Co., Ltd.	6.03	(5,000)	3,982
47	Nippon Denso Co., Ltd.	6.02	(53,000)	46,500
48	Ando Electric Co., Ltd.	6.00	(2,850)	1,682
49	Oki Electric Co., Ltd.	5.94	(23,200)	20,200
50	CKD Corp.	5.90	(2,900)	2,461
51	Toa Electronics Co., Ltd.	5.86	(286)	257
52	Daikyo Denki	5.80	(1,800)	1,400
52	Tateishi Denki	5.80	(15,500)	13,800
54	Nitsuko, Ltd.	5.64	(3,500)	2,961
55	Nitto Electric Industrial Co., Ltd.	5.63	(7,140)	6,009
56	Mitsubishi Electric Co., Ltd.	5.60	(106,000)	97,000
57	Nifco Inc.	5.59	(1,259)	748
58	Fuji Electric Co., Ltd.	5.56	(22,000)	20,600
59	Minolta Camera Co., Ltd.	5.40	(10,530)	8,841
60	Honda Motor Co., Ltd.	5.38	(120,000)	105,414
61	Komatsu, Ltd.	5.37	(32,000)	36,100
62	Ichikoyaku	5.30	(1,900)	1,713
63	Toyosa	5.24	(8,193)	6,405
64	Mazda Motor Corp.	5.12	(80,000)	68,200
64	Tokyo Keiki Co., Ltd.	5.12	(2,700)	2,679
66	Toyojozo Co., Ltd.	5.11	(3,683)	3,258
67	S.M.K. Corp.	5.07	(2,530)	2,086
67	Hirose Electric Co., Ltd.	5.07	(1,480)	1,300
69	Kokusai Electric Co., Ltd.	5.05	(4,300)	3,135
70	Koku Electronics	5.04	(3,027)	2,593
71	Shimadzu Corp.	5.00	(7,000)	5,500
71	Brother Industries, Ltd.	5.00	(9,500)	7,500
71	Shinto Paint Co., Ltd.	5.00	(1,600)	1,531
71	Rohm Co., Ltd.	5.00	(4,500)	3,633
75	Sony Magnascale Inc.	4.95	(500)	310
76	Citizen Watch Co., Ltd.	4.91	(7,500)	6,893
77	Sanyo Electric Co., Ltd.	4.83	(1,450)	1,321
78	Meiji Seika Kaisha Ltd.	4.80	(10,000)	10,000

[continued]

[Continuation of Table 8]

Rank-ing	Company name	Proceeds spent in developmental research in fiscal year 1985 (percent)	1985 developmental research expenditures (¥1 million)	1984 developmental research expenditures (¥1 million)
79	Taoka Chemical Co., Ltd.	4.75	(380)	348
80	Macksel	4.70	(8,000)	6,800
81	Sanyo Chemical Co., Ltd.	4.69	(2,580)	2,460
82	Hitachi Koki Co., Ltd.	4.67	(3,970)	3,556
83	Riken Keiki Fine Instruments Co., Ltd.	4.61	(360)	360
84	Bridgestone Corp.	4.57	(27,000)	26,000
85	Futaba Corp.	4.53	(3,565)	3,078
86	Dai Nippon Toryo Co., Ltd.	4.51	(2,530)	2,354
87	Mikuni Corp.	4.48	(2,000)	1,826
88	Oriental Photo Industrial Co., Ltd.	4.47	(600)	600
89	Nissan Motor Co., Ltd.	4.43	(170,000)	155,000
90	Toho Titanium Co., Ltd.	4.39	(900)	816
91	Aisan Industry Co., Ltd.	4.36	(2,600)	2,474
92	Tokyo Sanyo Electric Co., Ltd.	4.29	(23,000)	20,000
93	Mitsubishi Heavy Industries, Ltd.	4.27	(79,000)	80,300
94	Togami Electric Manufacturing Co., Ltd.	4.25	(600)	600
95	Daiichi Shoko Co., Ltd.	4.20	(692)	587
96	Toa Electric Co., Ltd.	4.18	(920)	850
97	Showa Manufacturing Co., Ltd.	4.16	(2,000)	1,953
98	Osaki Electric Manufacturing Co., Ltd.	4.08	(602)	486
99	Yaskawa Electric Manufacturing Co., Ltd.	4.03	(4,743)	3,864
100	Canon Electronics Inc.	4.00	(1,300)	1,052
100	TDK Corp.	4.00	(15,600)	14,145
100	Eagle Industry Co., Ltd.	4.00	(900)	713
100	Meidensha Electric Manufacturing Co., Ltd.	4.00	(4,810)	4,613
100	Star Manufacturing Co., Ltd.	4.00	(1,200)	1,000
100	Asahi Chemical Industry Co., Ltd.	4.00	(32,000)	28,000
106	Aiwa Co., LTd.	3.98	(800)	716
107	Yuki Goseiyaku	3.97	(350)	331
108	Shin-Etsu Chemical Industry Co., Ltd.	3.96	(9,446)	6,991
109	Toyota Motor Corp.	3.95	(240,000)	220,000
110	Denki Kagaku Kogyo K.K.	3.94	(8,200)	6,480
111	Matsushita Electrical Industrial Co., Ltd.	3.89	(23,000)	21,900
112	Shiba Ceramics	3.88	(2,100)	1,793
113	Mitsui Petrochemical Industries, Ltd.	3.87	(12,000)	9,496
114	Mitsubishi Rayon Co., Ltd.	3.85	(8,600)	7,500
115	Hosiden Electronics Co., Ltd.	3.83	(1,650)	1,150
116	Nepon Inc.	3.82	(308)	286
117	Mutoh Industry, Ltd.	3.81	(906)	978

[continued]

[Continuation of Table 8]

Ranking	Company name	Proceeds spent in developmental research in fiscal year 1985 (percent)	1985 developmental research expenditures (¥1 million)	1984 developmental research expenditures (¥1 million)
118	Kanegafuchi Chemical Industry, Ltd.	3.80	(7,600)	7,276
119	NOK Corp.	3.79	(4,700)	3,514
120	Sagami Rubber Industries, Co., Ltd.	3.78	(150)	130
121	Toyo Denki Seizo K.K.	3.77	(1,479)	1,822
122	Kyushu Refractories Co., Ltd.	3.76	(386)	358
123	Crown Radio Corp.	3.75	(1,500)	1,000
123	Kanto Seiki Co., Ltd.	3.75	(3,600)	2,738
125	Sokkisha Co., Ltd.	3.74	(500)	588
125	Mitsui High-Tec Inc.	3.74	(1,000)	600

(Note) Matsushita is the base industry

Source: Nikkei Company Report (86-I New Year Issue)

(3) The number of researchers grew by 3.1 percent, but the growth rate slowed. When the number of individuals engaged in research-related work in 1985 is looked at by occupational group, those responsible for the main research activities, "researchers," number 480,100 (447,700 of these are full-time) and account for 62.9 percent of all groups. Those who are responsible for assisting research activities, "research assistants," "technicians," and those research-related office work or other work number 100,500 individuals, 99,300 individuals, and 82,900 individuals, respectively.

The rate of increase over the previous year by occupational group was 3.1 percent for researchers, a 3.7 point reduction from the 6.8 percent rise in 1984. Lately the growth has been very limited. In addition the number of research assistants rose by 4.4 percent, technicians by 2.3 percent, and research related office workers and others by 0.9 percent.

Table 9. Developmental Research Expenditures by the Top 15 Companies
($1 million)

1.	General Motors	$2,602
2.	IBM	2,514
3.	Fort Motor	1,751
4.	United Technologies	971
5.	Du Pont	966
6.	General Electric	919
7.	Eastman Kodak	746
8.	Exxon	692
9.	Digital Equipment	631
10.	Hewlett-Packard	592
11.	Xerox	555
12.	ITT	518
13.	Dow Chemical	492
14.	Boeing	429
15.	Honeywell	429

Source: BUSINESS WEEK 22 March 1985, "Scoreboard Special"

(4) Companies had a large percentage of researchers in electrical and communications; research institutions in agriculture and forestry, veterinary medicine, and animal husbandry, and in universities, medicine and dentistry. In 1985 the number of full time researchers in the natural sciences was 382,600 individuals. By category, companies had 228,200 persons which is about 60 percent of the total; 121,700 individuals were in universities; and 32,800 individuals were in research institutions.

The proportion of full time researchers by specialty will be looked at within research bodies. For companies the largest percentage is in electrical and communications with 28.8 percent, followed by mechanical, marine, and aeronautics with 25.7 percent, and chemistry with 20.5 percent. These 3 fields account for 75 percent of the total while the remaining fields account for less than 6 percent each.

As for research institutions, agriculture and forestry, veterinary medicine, and animal husbandry have the largest number with 29.4 percent and chemistry has 11.6 percent. These two fields account for 41.0 percent of the total. The remaining fields account for less than 10 percent each.

In universities medicine and dentistry account for the majority with 52.7 percent. The remaining fields account for less than 8 percent each. (Table 12)

(1) 表10 研究関係従事者数の推移

(2) 年次	(3) 研究関係従事者数 (100人)					(4) 対前年増加率 (%)		
	総数 (5)	うち自然科学 (6)	(7) 割合 (%)	うち人文・社会科学 (8)	(9) 割合 (%)	総数 (10)	(11) 自然科学	人文・社会科学 (12)
55	6,248	5,376	86.1	473	7.6	4.7	4.8	5.8
56	6,550	5,652	86.3	491	7.5	4.8	5.1	3.8
57	6,763	5,876	86.9	485	7.2	3.3	4.0	−1.0
58	6,991	6,106	87.3	490	7.0	3.4	3.9	0.9
59	7,413	6,525	88.0	492	6.6	6.0	6.9	0.4
60	7,628	6,729	88.2	501	6.6	2.9	3.1	1.8

Key:

1. Table 10. Changes in Number of Individuals Engaged in Research Related Work
2. Annual
   55 - 1980
   56 - 1981
   57 - 1982
   58 - 1983
   59 - 1984
   60 - 1985
3. Number of individuals engaged in research related work (100s of individuals)
4. Rate of increase over previous year (%)
5. Total number
6. [Within] natural sciences
7. Proportion (%)
8. [In the] humanities and social sciences
9. Proportion (%)
10. Total number
11. Natural sciences
12. Humanities and social sciences

This trend in the companies is also evident in the Nikkei Company Report on the number of researchers by enterprise. In the top 20 companies there are 5 enterprises related to electrical and communications (Matsushita Ltd., Sharp Corp., Sanyo Electric Co., Ltd., Nippon Denso, and Matsushita Electric Works, Ltd.) 7 companies related to mechanical, marine, and aeronautics (Mazda Motor Corp, Kawasaki Heavy Industries, Ltd., Mitsubishi Heavy Industries Ltd., Nippon Kokan K.K., Hino Motors Ltd., Fuji Heavy Industries, Ltd., Ishikawajima-Harima Heavy Industries Co., Ltd.); and 6 companies in chemistry (Asahi Chemical Industry Co., Ltd., Sumitomo Chemical Co., Ltd., Mitsubishi Chemical Industries, Ltd., Kao Corp., TEIJIN Ltd., and TORAY Industries, Inc.) These 3 fields account for 90 percent of the researchers. (Table 13)

(1) 表11 職種，研究主体別研究関係従事者数の推移

(2) 区分		(3) 総数	(4) 職種別						(5) 研究主体別		
			(6) 研究者	(7) 本務者	(8) 兼務者	(9) 研究補助者	(10) 技能者	(11) 研究事務その他の関係者	(12) 会社等	(13) 研究機関	(14) 大学等
(15) 研究関係従事者数 (100人)	(18) 55年	6 248	3 871	3 635	236	777	870	730	3 319	710	2 219
	56	6 550	4 052	3 794	258	837	904	757	3 513	761	2 276
	57	6 763	4 199	3 926	273	873	912	779	3 660	817	2 286
	58	6 991	4 362	4 060	302	901	933	795	3 778	833	2 380
	59	7 413	4 658	4 353	304	963	971	822	4 122	860	2 431
	60	7 628	4 801	4 477	324	1 005	993	829	4 276	876	2 476
(16) 対前年増加率 (%)	(18) 55年	4.7	6.6	6.5	9.4	1.4	4.4	−1.0	7.0	−1.6	3.5
	56	4.8	4.7	4.4	9.4	7.7	4.0	3.6	5.8	7.2	2.6
	57	3.3	3.6	3.5	5.8	4.4	0.8	2.9	4.2	7.3	0.5
	58	3.4	3.9	3.4	10.5	3.2	2.4	2.1	3.2	2.0	4.1
	59	6.0	6.8	7.2	5.8	6.8	4.0	3.4	9.1	3.3	2.1
	60	2.9	3.1	2.8	6.5	4.4	2.3	0.9	3.7	1.9	1.9
(17) 構成比 (%)	(18) 55年	100.0	62.0	58.2	3.8	12.4	13.9	11.7	53.1	11.4	35.5
	60	100.0	62.9	58.7	4.2	13.2	13.0	10.9	56.1	11.5	32.5

Key:

1. Table 11. Changes in Number of Individual Research Groups and Research Related Jobs
2. Classification
3. Total number
4. Job classification
5. Research group classification
6. Researchers
7. Full time researchers
8. Part time researchers
9. Research assistants
10. Skilled workers
11. Research related office workers and others
12. Company
13. Research institutions
14. Universities
15. Number of individuals in research related work (100s of individuals)
16. Rate of increase over previous year
17. Comparative make-up
18. Year
    - 55 - 1980
    - 56 - 1981
    - 57 - 1982
    - 58 - 1983
    - 59 - 1984
    - 60 - 1985

表12　自然科学の専門別研究本務者数(60年)

	専門別	総数	会社等	研究機関	大学院
研究本務者数(100人)	総数	3,826	2,282	328	1,217
	数学・物理	234	124	20	90
	化学	546	469	38	40
	生物	69	31	6	32
	機械・船舶・航空	666	586	27	53
	電気・通信	744	658	25	61
	農林・獣医・畜産	227	63	96	67
	医学・歯学	651	2	8	641
	薬学	121	73	9	38
	その他	568	277	97	194
構成比(%)	総数	100.0	100.0	100.0	100.0
	数学・物理	6.1	5.4	6.0	7.4
	化学	14.3	20.5	11.6	3.3
	生物	1.8	1.4	1.9	2.6
	機械・船舶・航空	17.4	25.7	8.4	4.3
	電気・通信	19.4	28.8	7.6	5.0
	農林・獣医・畜産	5.9	2.8	29.4	5.5
	医学・歯学	17.0	0.1	2.5	52.7
	薬学	3.2	3.2	2.9	3.1
	その他	14.9	12.1	29.7	16.0

Key:

1. Table 12. Number of Full Time Researchers in Natural Science Specialties (1985)
2. Specialties
3. Total number
4. Company
5. Research institution
6. University
7. Full time researchers (100's of individuals)
8. Comparative make-up
9. Total number
10. Mathematics and physics
11. Chemistry
12. Biology
13. Mechanical; marine; aeronautics
14. Electric; communication
15. Agriculture, forestry and fisheries; veterinary medicine; animal husbandry
16. Medicine and dentistry
17. Pharmacology
18. Others
19. Total number
20. Mathematics and physics
21. Chemistry
22. Biology
23. Mechanical; marine; aeronautics
24. Electric; communication
25. Agriculture, forestry and fisheries; veterinary medicine; animal husbandry
26. Medicine and dentistry
27. Pharmacology
28. Others

Table 13. Ranking of Employed Researchers (Subject: "Survey of Developmental Research Expenditures," approximately 750 companies replied)

Ranking	Company	Fiscal year 1985 actual number and estimate of researchers (total employees)	Fiscal year 1984 actual number of researchers (total employees)
1	Matsushita Ltd.	14,000(39,300)	13,500(39,091)
2	Sharp Corp	5,680(22,820)	5,006(22,314)
3	Mazda Corp.	5,300(27,600)	4,900(27,406)
4	Sanyo Electric Co., Ltd.	3,100(20,900)	2,841(19,389)
5	Nippon Denso Co., Ltd.	2,900(3,300)	2,600(31,117)
6	Kawasaki Heavy Industries, Ltd.	2,800(22,300)	2,700(23,162)
7	Asahi Chemical Industry Co., Ltd.	2,500(15,897)	2,500(15,677)
8	Mitsubishi Heavy Industries Ltd.	2,200(51,000)	2,200(51,717)
9	Matsushita Electric Works, Ltd.	1,950(13,280)	1,768(13,101)
10	Sumitomo Chemical Co., Ltd.	1,780(6,980)	1,700(6,843)
11	Mitsubishi Chemical Industries, Ltd.	1,750(8,135)	1,521(8,135)
12	Olympus Optical Co., Ltd.	1,598(4,417)	1,495(3,876)
13	Takeda Chemical Industries, Ltd.	1,550(10,900)	1,528(10,998)
14	Nippon Kokan K.K.	1,542(33,154)	1,492(33,295)
15	Kao Corp.	1,500(6,000)	1,280(5,603)
15	TEIJIN, Ltd.	1,500(7,000)	1,500(7,166)
15	TORAY Industries, Inc.	1,500(12,633)	1,500(12,633)
17	Hino Motors, Ltd.	1,450(8,400)	1,400(8,363)
18	Fujisawa Pharmaceutical Co., Ltd.	1,400(5,746)	1,400(5,746)
18	Fuji Heavy Industries, Ltd.	1,400(14,500)	1,300(13,933)
18	Ishikawajima-Harima Heavy Industries, Ltd.	1,400(25,564)	1,400(25,564)
21	Fuji Electric Co., Ltd.	1,277(14,309)	1,251(14,026)
22	Dainippon Ink and Chemicals Inc.	1,216(6,100)	1,183(5,992)
23	Mitsui Toatsu Chemicals, Inc.	1,200(5,300)	1,200(5,435)
24	Shionogi & Co., Ltd.	1,150(6,410)	1,139(6,552)
24	Sumitomo Electric Industries, Ltd.	1,150(12,427)	1,100(12,427)
26	Asahi Glass Co., Ltd.	1,100(9,560)	1,000(9,152)
27	Kobe Steel, Ltd.	1,000(28,928)	970(28,928)
27	The Shimizu Construction Co., Ltd.	1,000(10,150)	1,000(10,181)

Ranking	Company	Fiscal year 1985 actual number and estimate of researchers (total employees)	Fiscal year 1984 actual number of researchers (total employees)
29	Nissan Diesel Motor Co., Ltd.	981(6,300)	975(6,467)
30	Toyo Cloth Co., Ltd	960(10,616)	900(11,117)
31	Ajinomoto Co., Inc.	947(5,700)	923(5,780)
32	Mitsui Petrochemical Industries, Ltd.	923(4,331)	924(4,257)
33	Mitsui, Ltd.	900(5,400)	911(5,444)
33	Toyoda Automatic Loom Works, Ltd.	900(6,550)	816(6,452)
35	Denki Kagaku Kogyo K.K.	810(4,000)	720(3,940)
35	Nissan Shatai Co., Ltd.	810(7,089)	800(6,889)
37	Sekisui Chemical Co., Ltd.	790(6,100)	705(6,063)
38	KURARAY Co., Ltd.	770(5,900)	708(6,049)
39	The Furukawa Electric Co., Ltd.	750(7,500)	700(7,533)
39	Mitsubishi Rayon Co., Ltd.	750(3,997)	700(3,997)
40	Nippon Mining Co., Ltd.	730(6,000)	725(5,986)
41	Tanabe Seiyaku Co., Ltd.	693(5,434)	--(5,386)
42	Lion Corp.	665(3,887)	601(3,847)
43	Gosei Rubber	634(2,700)	602(2,623)
44	Toyoda Gosei Co., Ltd.	607(4,964)	583(4,787)
45	Eisai Co., Ltd.	600(3,635)	572(3,525)
45	Toyo Soda Mfg. Co., Ltd.	600(4,000)	510(3,843)
47	Taisho Pharmaceutical Co., Ltd.	589(3,667)	548(3,443)
48	Kanefaguchi Chemical Industry, Ltd.	580(2,990)	571(2,962)
49	Yamanouchi Pharmaceutical Co., Ltd.	575(2,928)	568(2,804)
50	UNITIKA, Ltd.	572(5,710)	550(5,792)
51	Mitsubishi Petrochemical Co., Ltd.	560(2,382)	520(2,290)
52	TDK Corp.	550(7,700)	500(7,609)
52	Nippon Kayaku Co., Ltd.	550(3,186)	550(3,383)
54	Sumitomo Rubber Industries, Ltd.	540(4,800)	530(4,700)
55	Nihon Radiator Co., Ltd.	538(4,970)	482(4,916)
56	Nitto Electric Industrial Co., Ltd.	530(3,055)	477(2,846)
57	Kureha Chemical Industry Co., Ltd.	500(2,534)	500(2,514)
57	Fujikura, Ltd.	500(3,670)	500(3,672)
57	Kyocera Corp.	500(12,500)	475(12,930)

Ranking	Company	Fiscal year 1985 actual number and estimate of researchers (total employees)	Fiscal year 1984 actual number of researchers (total employees)
57	Sumitomo Metal Mining Co., Ltd.	500(3,607)	510(3,626)
57	Hitachi Metals, Ltd.	500(9,400)	430(9,359)
62	Toyo Ink Mfg. Co., Ltd.	495(2,945)	477(2,900)
63	Daiichi Seiyaku Co., Ltd.	470(3,050)	470(2,943)
64	Nippon Sheet Glass	435(4,100)	410(3,985)
65	Ishihara Sangyo Kaisha, Ltd.	421(1,514)	395(1,499)
66	Kanto Seiki Co., Ltd.	410(3,300)	371(3,062)
66	Yoshitomi Pharmaceutical Industries, Ltd.	410(2,370)	400(2,346)
68	Oji Paper Co., Ltd.	400(5,494)	391(5,599)
68	Shiseido Co., Ltd.	400(--)	390(14,081)
70	Nippon Paint Co., Ltd.	394(2,570)	367(2,562)
71	Kirin Brewery Co., Ltd.	390(7,600)	330(7,519)
72	Toyosa	381(3,192)	365(3,145)
73	Chugai Pharmaceutical Co., Ltd.	380(3,370)	383(3,314)
74	Tokushu Togyo Co., Ltd.	370(3,950)	361(3,915)
75	Aiwa Co., Ltd.	361(3,084)	369(3,075)
76	Citizen Watch Co., Ltd.	360(3,210)	352(3,154)
77	Nitsuko, Ltd.	357(1,018)	292(944)
78	Yaskawa Electric Mfg.Co.,Ltd.	356(4,350)	323(4,361)
79	Sogyo Denshi	353(2,055)	319(1,949)
80	Hitachi Shipbuilding and Engineering Co., Ltd.	350(14,000)	349(16,757)
81	Tokuyama Soda Co., Ltd.	340(2,372)	300(2,341)
81	Meidensha Electric Mfg. Co., Ltd.	340(4,136)	330(4,080)
81	Akebono Brake Industry Co., Ltd.	340(2,600)	289(2,692)
81	Mitsui Shipbuilding and Engineering Co., Ltd.	340(10,700)	347(11,146)
84	Tokyo Gas Co., Ltd.	328(12,928)	347(12,827)
85	Tokyo Juki Industrial Co.Ltd.	327(3,004)	255(2,929)
86	Catalysts and Chemical Industries Co., Ltd.	326(1,813)	309(1,757)
87	CKD Corp.	325(1,350)	296(1,281)
87	Atsugi Motor Parts Co.,Ltd.	325(4,641)	305(4,434)
89	Koku Denshi	320(2,130)	298(2,005)
89	Toyama Chemical Co., Ltd.	320(2,100)	316(2,094)
89	Nisshin Steel Co., Ltd.	320(8,750)	398(8,762)
92	Sanyo Chemical Industries,Ltd.	311(1,072)	306(1,051)
93	Kaken Pharmaceutical Co.,Ltd.	310(2,030)	297(2,030)
94	Nippon Light Metal Co., Ltd.	300(4,150)	305(4,098)
94	Kansai Paint Co., Ltd.	300(2,800)	294(2,800)

Ranking	Company	Fiscal year 1985 actual number and estimate of researchers (total employees)	Fiscal year 1984 actual number of researchers (total employees)
94	Nippon Shinyaku Co.,Ltd.	300(1,790)	300(1,793)
94	Rohm Co., Ltd.	300(2,100)	224(1,944)
94	Ohbayashi-gumi, Ltd.	300(10,000)	277(9,988)
94	Sumitomo Bakelite Co.,Ltd.	300(2,776)	285(2,655)
100	Dai Nippon Toryo Co.,Ltd.	290(1,050)	288(1,046)
100	Hitachi Koki Co., Ltd.	290(2,520)	279(2,491)
100	Hitachi Cable, Ltd.	290(5,100)	266(5,061)
103	Anritsu Electric Co., Ltd.	280(2,790)	260(2,679)
104	Onoda Cement Co., Ltd.	263(2,063)	242(2,075)
105	Glory, Ltd.	260(1,140)	222(1,035)
105	Nissan Chemical Industries, Ltd.	260(1,705)	260(1,684)
107	Kajima Construction Co.,Ltd.	252(13,200)	257(13,042)
108	Sekitetsuko	250(4,000)	250(4,185)
108	Mitsubishi Belting Ltd.	250(2,520)	238(2,481)
110	Ono Pharmaceutical Co.,Ltd.	247(1,490)	211(1,441)
111	Mitsui Mining and Smelting Co., Ltd.	241(4,827)	218(4,736)
112	Taisei Corporation	240(12,250)	240(12,236)
112	Amada Co., Ltd.	240(1,500)	204(1,407)
112	Se Glass	240(2,600)	195(2,524)
115	Kokusai Electric Co., Ltd.	235(1,550)	189(1,363)
116	National House Industrial Co., Ltd.	234(2,143)	188(2,108)
117	Dai-ichi Kogyo Seiyaku Co., Ltd.	230(920)	223(991)
118	Fujitec Co., Ltd.	227(1,944)	201(1,743)
119	Banyu Pharmaceutical Co.,Ltd.	220(2,900)	180(1,816)
120	Nisshin Spinning Co.,Ltd.	218(6,609)	190(6,518)

Note: Matsushita Ltd. is the base industry.

Source: Nikkei Company Report (86-I New Year issue)

III. Technology Exchange

(1) Technology exports (payments received) have increased satisfactorily; technology imports (payments made) are level. In technology trade by companies in fiscal year 1984 there were 5,426 cases of technology exports, a reduction compared to the previous fiscal year (6,403 cases), yet payments received amounted to ¥277.5 billion, a satisfactory increase of 15.2 percent over the previous fiscal year, which does not, however, match the remarkably high growth of the previous fiscal year (30.3 percent). There were 7,316 cases of technology imports, also a reduction when compared to exports and to the previous fiscal year (7,839 cases). Payments were ¥281.4 billion, a limited growth of 0.8 percent over the previous fiscal year.

As a result the ratio of payments made to payments received was 1.01, striking a balance between exports and imports, and a further reduction from the previous fiscal year's ratio of 1.16.

(2) There was an excess of exports in new technology trade with a continued rise. Within technology trade, contracts that were concluded in fiscal year 1984 show that for new technology trade, there were 1,824 cases of technology exports with payments received of ¥90.9 billion, showing a trend similar to all technology trade with a decrease in cases over the previous fiscal year. Payments received, however, showed a strong rise of 21.4 percent.

The number of cases of new technology imports was 982 with payments of ¥31.8 billion, showing a decrease both in number of cases and in payments over the last fiscal year. In particular, payments showed a large decline of 25.0 percent. As a result, there was an excess of exports which continued to increase for new technology trade. Payments made were 0.35 times those of payments received, a continued decrease from the previous fiscal year. (Table 14)

(3) The electrical machine industry has the most exports and imports. In the key manufacturing industries, exports were largest in the electrical machine industry with ¥47.2 billion, followed by the transportation industry with ¥39.8 billion, the chemical industry with ¥37.5 billion, and the iron-and-steel industry with ¥32.4 billion. Compared with the last fiscal year the electrical machine industry showed a rise of 32.6 percent and the transportation industry had a rise of 37.4 percent, showing strong growths of over 30.0 percent. The chemical industry showed a satisfactory rise of 19.3 percent but the iron-and-steel industry did not prosper and had a 19.3 percent decline.

Next, looking at imports, the electrical machine industry was conspicuous with ¥94.9 billion. This was followed by the transportation industry with ¥55.2 billion, the chemical industry with ¥40.8 billion, and the machine industry with ¥23.9 billion. The top three importing industries are the top exporters. The rate of increase over the last fiscal year was satisfactory for the transportation industry with a rise of 17.7 percent, but the other industries shifted to market weakness, either with losses, or increases at about the 3 percent level.

(1) 表14 技術交流（技術貿易）の推移

(2) 区分		(3) 技術輸出 (5) 件数	(6) 受取額 (億円)	(7) 対前年度増加率 (%)	(4) 技術輸入 (8) 件数	(9) 支払額 (億円)	対前年度増加率 (10) (%)	支払額 (11) / 受取額 (倍)
(12) 総数	54年度	3,667	1,331	9.1	7,012	2,410	25.5	1.81
	55 (14)	4,103	1,596	19.9	7,248	2,395	−0.6	1.50
	56	4,877	1,751	9.7	7,207	2,596	8.4	1.48
	57	4,738	1,849	5.6	6,936	2,826	8.9	1.53
	58	6,403	2,409	30.3	7,839	2,793	−1.2	1.16
	59	5,426	2,775	15.2	7,316	2,814	0.8	1.01
(13) 新規	54年度	1,087	521	10.5	1,020	268	−29.8	0.51
	55 (14)	1,237	743	42.6	919	277	3.2	0.37
	56	2,017	708	−4.7	844	249	−10.0	0.35
	57	1,970	633	−10.5	929	444	78.4	0.70
	58	2,494	749	18.3	1,073	424	−4.5	0.57
	59	1,824	909	21.4	982	318	−25.0	0.35

Key:

1. Table 14. Changes in Technology Exchange (technology trade)
2. Classification
3. Technology exports
4. Technology imports
5. Number of cases
6. Payments received (¥ 100 million)
7. Rate of increase over previous year (%)
8. Number of cases
9. Payments made (¥ 100 million)
10. Rate of increase over previous year (%)
11. Payments made/payments received (times)
12. Total number
13. New technology
14. Fiscal year
    - 54 - 1979
    - 55 - 1980
    - 56 - 1981
    - 57 - 1982
    - 58 - 1983
    - 59 - 1984

When exports and imports are compared, at the top of the list for the high-tech industries are the electric machine industry with a multiple of 2.01, the machine industry with a multiple of 2.10, and the transportation industry with a multiple of 1.39, and as before the excess of imports is remarkable. Even in the manufacturing industry, the only industries with an excess of exports are the iron-and-steel industry, the automobile industry, the ceramics industry, and the synthetic chemical and fiber industry. (Table 15)

That Japan's changing from an excess importer of technology to an excess exporter of technology is clearly shown by trends in technology trade by enterprise. According to the Nikkei Company Report, it is clear that the top ranking big companies, of which Toyota Motor Corp., Nippon Steel Corp., Toshiba, Ltd., and Mitsubishi Heavy Industries, Ltd. have the lead, and are increasing the amount of payments received. (Table 16)

(4) There is an excess of exports to Asia and Africa and an excess of imports from Europe and the United States. Technology trade with trading partners is largest in exports to the United States at ¥65.9 billion, followed by China (including Taiwan) with ¥53.1 billion, South Korea with ¥14.9 billion, and Indonesia with ¥13.6 billion. Looked at by region, Asia (excluding western Asia) was the largest with ¥112.5 billion and accounted for 40 percent of total technology exports. This was followed by North America with ¥71.9 billion, Europe with ¥40.7 billion, Western Asia with ¥30.8 billion, and Africa with ¥12.8 billion.

Technology imports from the United States are by far the largest with ¥193 billion, which is 68.6 percent of total technology imports. The remainder is almost completely accounted for by Europe with ¥17.8 billion from West Germany, ¥16 billion from Switzerland, ¥14.1 billion from the Netherlands, ¥13.2 billion from England, and ¥104 billion from France, a total of ¥86.7 billion from all of Europe.

As for the balance of trade by region there is a large excess of technology imports from the technologically advanced countries of North America and Europe; with the other regions, in particular with Asia, there is a large excess of technology exports. As before we are clearly the receivers of technology from the advanced countries.

In this connection, when the rate of payments made to payments received is compared for the last 5 years, North America went from a multiple of 6.78 to 2.70 and Europe went from a multiple of 3.65 to 2.13. Both have been decreasing so the excess of imports has been decreasing. (Table 17)

(1) 表15　産業別技術交流（技術貿易）（59年度）

(2) 産業	(3) 技術輸出			(4) 技術輸入			(11) 支払額／受取額 (倍)
	(5) 件数	(6) 受取額 (億円)	対前年度増加率 (%) (7)	(8) 件数	(9) 支払額 (億円)	(10) 対前年度増加率 (%)	
(12) 全産業	5,426	2,775	15.2	7,316	2,814	0.8	1.01
(13) 農林水産業	18	2	−36.3	—	—	—	—
(14) 鉱業	15	4	18.7	14	2	9.0	0.48
(15) 建設業	712	446	49.0	307	23	−47.8	0.05
(16) 製造業	4,660	2,319	10.6	6,979	2,769	1.5	1.19
(17) 食品工業	175	68	87.4	178	95	9.1	1.39
(18) 繊維工業	106	39	76.1	215	94	70.4	2.45
(19) パルプ・紙工業	47	14	26.3	36	14	117.0	1.00
(20) 出版・印刷業	12	1	141.9	33	5	−40.2	7.09
(21) 化学工業	888	375	19.3	784	408	−3.6	1.09
(22) 総合化学・化学繊維工業	421	191	10.6	429	153	−12.8	0.80
(23) 油脂・塗料工業	169	26	26.2	153	37	3.5	1.42
(24) 医薬品工業	204	137	37.7	123	138	11.7	1.01
(25) その他の化学工業	94	21	−3.0	79	79	−9.5	3.78
(26) 石油製品・石炭製品工業	31	6	−39.1	97	30	11.1	4.79
(27) プラスチック製品工業	57	5	−19.4	92	16	−7.3	3.10
(28) ゴム製品工業	53	23	20.2	118	33	−17.1	1.40
(29) 窯業	196	112	16.6	186	84	24.5	0.75
(30) 鉄鋼業	411	324	−19.3	316	56	−68.4	0.17
(31) 非鉄金属工業	133	19	−18.1	170	51	39.7	2.65
(32) 金属製品工業	133	13	−16.6	199	36	38.6	2.83
(33) 機械工業	543	114	6.3	1,109	239	−16.1	2.10
(34) 電気機械工業	1,095	472	32.6	2,190	949	3.2	2.01
(35) 電気機械器具工業	434	142	21.0	437	337	21.5	2.38
(36) 通信・電子・電気計測器工業	661	330	38.4	1,753	612	−4.6	1.86
(37) 輸送用機械工業	526	398	37.4	883	552	17.7	1.39
(38) 自動車工業	304	272	47.7	271	103	−3.3	0.38
(39) その他の輸送用機械工業	222	126	19.5	612	450	23.9	3.57
(40) 精密機械工業	71	18	−55.4	191	44	−0.4	2.43
(41) その他の工業	183	317	−8.6	182	63	54.1	0.20
(42) 運輸・通信・公益業	21	4	−31.2	16	21	10.8	5.23

Key:

1. Table 15. Technology Exchange by Industry (technology trade) (fiscal year 1984)
2. Industry
3. Technology exports
4. Technology imports
5. Number of cases
6. Payments received (¥100 million)
7. Rate of increase over previous year (%)
8. Number of cases
9. Payments made (¥100 million)

[Key continues on following page]

10. Rate of increase over previous year (%)
11. Payments made/payments received (times)
12. All industries
13. Agriculture, forestry and fishery industry
14. Mining industry
15. Construction industry
16. Manufacturing industry
17. Food industry
18. Textile industry
19. Pulp and paper industry
20. Publishing and printing industry
21. Chemical industry
22. Synthetic chemical and fiber industry
23. Oil, fat, and paint industry
24. Pharmaceutical industry
25. Other chemical industries
26. Petroleum and coal industry
27. Plastic products industry
28. Rubber products industry
29. Ceramics industry
30. Iron-and-steel industry
31. Nonferrous metals industry
32. Metal goods industry
33. Machine industry
34. Electrical machine industry
35. Electrical appliance industry
36. Communications; electronics; electrical measuring instruments industry
37. Transportation industry
38. Automobile industry
39. Other transportation industries
40. Precision machine industry
41. Other industries
42. Transportation; communication; public service industry

Table 16. Ranking of Quantity of Received Technology
(Source: "Survey of Developmental Research Expenditures," approximately 750 companies replied)

Ranking	Company	Quantity of received technology fiscal year 1985 (fiscal year 1984)
1	Matsushita, Ltd.	12,000(10,854)
2	Hitachi, Ltd.	10,447(9,091)
3	Toyama Chemical Co., Ltd.	5,500(5,656)
4	Mitsui Petrochemical Industries, Ltd.	4,175(4,646)
5	Fujisawa Pharmaceutical Co., Ltd.	2,800(2,725)
6	Nippon Kokan K.K.	2,300(2,050)
7	Takeda Chemical Industries, Ltd.	2,000(1,912)
7	Mazda Motor Corp.	2,000(2,151)
9	Kawasaki Heavy Industries, Ltd.	1,800(1,729)
10	Nippon Paint Co., Ltd.	1,620(1,300)
11	Sumitomo Chemical Co., Ltd.	1,600(1,254)
12	Mitsui Toatsu Chemicals, Inc.	1,400(3,058)
13	Mitsui Mining and Smelting Co.,Ltd.	1,200(961)
13	Mitsubishi Chemical Industries, Ltd.	1,200(1,000)
15	Mitsubishi Petrochemical Co., Ltd.	1,000(554)
16	Fuji Electric Co., Ltd.	800(727)
17	Sankyo Co., Ltd.	700(795)
18	Toyoda Spinning and Weaving Co.,Ltd.	690(689)
19	Kaken Pharmaceutical Co., Ltd.	650(437)
20	Toyo Soda Mfg. Co., Ltd.	592(388)
21	Catalysts and Chemicals Industries Co., Ltd.	560(534)
22	TDK Corp.	530(189)
23	Nitto Boseki Co., Ltd.	520(172)
24	Onoda Cement Co., Ltd.	500(483)
24	Ishihara Sangyo Kaisha, Ltd.	500(269)
26	Asahi Concrete Works Co., Ltd.	480(455)
27	Aiwa Co., Ltd.	408(362)
28	Fujitec Co., Ltd.	350(336)
29	Kyocera Corp.	350(388)
30	Nippon Kayaku Co., Ltd.	341(327)
31	Kurabo Industries, Ltd.	336(327)
32	Toho Zinc Co., Ltd.	330(0)
33	Nissan Diesel Motor Co., Ltd.	310(83)
34	Mitsubishi Belting, Ltd.	309(108)
34	Hino Motors, Ltd.	309(352)
36	Kanzaki Paper Mfg. Co., Ltd.	300(290)
36	Chiyoda Chemical Engineering and Construction Co., Ltd.	300(250)
36	Mazda Motor Corp.	300(292)
39	Japan Storage Battery Co., Ltd.	288(261)
40	Nitsuko, Ltd.	255(292)

Ranking	Company	Quantity of received technology fiscal year 1985 (fiscal year 1984)
41	The Japan Steel Works, Ltd.	250(553)
42	Futaba Corporation	233(150)
43	Nikki, Ltd.	230(63)
44	Itagarasu	200(262)
44	Tokyo Steel Mfg. Co., Ltd.	200(--)
46	Hitachi Cable, Ltd.	190(166)
47	Misawa, Ltd.	183(181)
48	INAX	180(165)
49	Sekonic Co., Ltd.	176(119)
50	Teikoku Kako Co., Ltd.	117(166)
51	Chugai Pharmaceutical Co., Ltd.	170(165)
52	Olympus Optical Co., Ltd.	167(148)
53	Shionogi & Co., Ltd.	161(376)
54	Asahi Denka Kogyo K.K.	155(232)
55	Daiichi Seiyaku Co., Ltd.	150(698)
55	Nisshin Steel Co., Ltd.	150(160)
55	Tokyo Gas Co., Ltd.	150(148)
55	Taisei Corporation	150(130)
59	Kumagai Gumi Co., Ltd.	149(19)
60	Rutsubo	125(152)
60	Nissin Food Products, Ltd.	125(135)
62	Daihen	124(--)
62	Sumitomo Metal Industries, Ltd.	124(165)
64	Aisan Industry Co., Ltd.	120(36)
64	Fujikura Co., Ltd.	120(119)
64	Furukawa Co., Ltd.	120(24)
67	Press Kogyo Co., Ltd.	117(69)
68	Akebono Brake Industry Co., Ltd.	110(139)
68	Shinko Electric Co., Ltd.	110(46)
68	Nosanko	110(104)
68	Daido-Maruta Finishing Co., Ltd.	110(96)
68	Stanley Electric Co., Ltd.	110(144)
68	Meidensha Electric Co., Ltd.	110(151)
68	Denki Kagaku Kogyo K.K.	110(150)
75	Oji Paper Co., Ltd.	100(170)
75	Se Glass	100(146)
75	Hitachi Metals, Ltd.	100(78)
75	Daiichi Shoko Co., Ltd.	100(97)
75	Mori Seiki Co., Ltd.	100(0)
75	Tokyo Cosmos Electric Co., Ltd.	100(1)
81	Kajima Corp.	95(78)
82	Fuji Heavy Industries, Ltd.	90(65)
82	Mitani Sekisan Co., Ltd.	90(47)
84	Mitsui Shipbuilding and Engineering Co., Ltd.	88(47)
84	Matsushita Electric Works, Ltd.	88(83)
86	Chichibu Cement Co., Ltd.	87(74)

Ranking	Company	Quantity of received technology fiscal year 1985 (fiscal year 1984)
87	Toyoda Machine Works, Ltd	86(71)
88	The Toyo Chemical Co., Ltd.	82(73)
89	Shimizu Construction Co., Ltd.	80(80)
89	Toyo Keiki Co., Ltd.	80(80)
89	Howa Machinery, Ltd.	80(84)
89	Toyo Ink Mfg. Co., Ltd.	80(79)
89	Toshin Steel Co., Ltd.	80(77)
94	Nikon Parkerizing	78(36)
95	Tokyo Steel Manufacturing Co., Ltd.	75(5)
96	Nitto Electric Industries Co., Ltd.	72(125)
97	Chugoku Marine Paints, Ltd.	70(69)
97	Nikkiso Co., Ltd.	70(35)
99	Chugai Ro Co., Ltd.	47(46)
100	Tokushu Togyo Co., Ltd.	65(69)
101	Daikin Manufacturing Co., Ltd.	62(55)
102	Tsurumi Manufacturing Co., Ltd.	60(60)
103	Eiyabu	59(8)
104	Nikken Chemicals Co., Ltd.	57(140)
105	Nippon Hume Pipe Co., Ltd.	56(22)
106	Atsugi Motor Parts Co., Ltd.	54(65)
107	Totetsu Kogyo Co., Ltd.	50(78)
107	Hashimoto Fuo	50(37)
107	Nippon Hodo Co., Ltd.	50(44)
107	Yoshitomi Pharmaceutical Industries,Ltd.	50(50)
107	Kodama Chemical Industry Co., Ltd.	50(37)
112	Nippon Denshi	45(54)
112	Tokushu Toryo Co., Ltd.	45(41)
114	Seiren Co., Ltd.	41(48)
115	Tokyo Tanabe Co., Ltd.	40(31)
115	Nagatanien-hondo Co., Ltd.	40(42)
115	Hitachi Shipbuilding & Engineering Co., Ltd.	40(41)
115	Shinto Paint Co., Ltd.	40(39)
115	Maruichi Steel Tube, Ltd.	40(40)
115	Suzuki Motor Co., Ltd.	40(30)
115	Fumakilla, Ltd.	40(38)
115	Daiichi Denko Co., Ltd.	40(38)
123	Harima Refractories Co., Ltd.	35(16)
123	Haneda Hume Pipe Co., Ltd.	35(--)
123	Teijin Seiki Co., Ltd.	35(0)
123	Mitsubishi Pencil Co., Ltd.	35(47)
123	Komatsu Seiren Co., Ltd.	35(39)
128	Mitsubishi Steel Mfg. Co., Ltd.	34(34)
129	Kyushu Refractories Co., Ltd.	33(25)
129	Bairin	33(40)
131	Osaka Titanium Co., Ltd.	32(32)
132	Japan Medical Supply Co., Ltd.	30(30)
132	Okuma Machinery Works, Ltd.	30(110)

Ranking	Company	Quantity of received technology fiscal year 1985 (fiscal year 1984)
132	Nisshin Electric Co., Ltd.	30(24)
132	Topre Corp.	30(27)
132	Kokusan Denki Co., Ltd.	30(6)
137	Toyojozo Co., Ltd.	29(64)
138	Kanto Seiki Co., Ltd.	28(22)
139	Nisco Inc.	25(26)
139	Inoue Kinzoku Kogyo Co., Ltd.	25(--)
139	Ishizuka Glass Co., Ltd.	25(19)
142	Dai Nippon Toryo Co., Ltd.	24(23)
142	Toshiba Ceramics Co., Ltd.	24(24)
142	Kobunshi	24(52)
142	Ohbayashi-gumi, Ltd.	24(23)
146	Dainippon Construction	23(0)
146	Spindo	23(17)
148	Kasai Kogyo Co., Ltd.	22(21)
148	Yamato International Inc.	22(12)
150	Japan Servo Co., Ltd.	21(33)
150	Toho Chemical Industry Co., Ltd.	21(23)
150	Nippon Cable System Inc.	21(14)
153	Noritake Co., Ltd.	20(18)
153	The Chugoku Electric Power Co., Ltd.	20(19)
153	Takisawa Machine Tool Co., Ltd.	20(11)
153	The Okamoto Co., Ltd.	20(15)
153	Ono Pharmaceutical Co., Ltd.	20(35)
153	Nippon Spring Co., Ltd.	20(17)
153	Chuo Spring Co., Ltd.	20(54)
153	Showa Mfg. Co., Ltd.	20(30)
153	Aica Kogyo Co., Ltd.	20(20)
153	Nihon Kentetsu Co., Ltd.	20(0)
153	Gunze, Ltd.	20(16)
153	Kokusai Electric Co., Ltd.	20(24)
153	Nippon Light Metal Co., Ltd.	20(20)
166	Yamamura Glass Co., Ltd.	18(37)
167	Tokyo Construction Co., Ltd.	17(20)
167	Osaka Oxygen Industries, Ltd.	17(12)
167	Danto Co., Ltd.	17(17)
167	Aoki Construction Co., Ltd.	17(5)

Note: Matsushita is the base industry
Unit: ¥1 million

(1) 表17 主な国別等技術交流（技術貿易）(59年度)

(2) 主な相手国	(3) 技術輸出 (4) 件数	(5) 受取額 (億円)	(6) 技術輸入 (7) 件数	(8) 支払額 (億円)	(9) 支払額/受取額 (倍)
(10) 総数	5,426	2,775	7,316	2,814	1.01
(11) アジア（西アジアを除く）	2,549	1,125	63	3	0.00
(12) 中国	918	531	53	2	0.00
(13) うち台湾	512	100	51	1	0.01
(14) シンガポール	115	91	—	—	—
(15) 韓国	598	149	8	1	0.00
(16) タイ	218	83	—	—	—
(17) インドネシア	228	136	1	X	X
(18) マレーシア	119	50	—	—	—
(19) フィリピン	111	6	—	—	—
(20) インド	142	45	—	—	—
西アジア	386	308	2	X	X
(22) イラク	221	85	—	—	—
北アメリカ	(23) 94[illegible]	719	4,437	1,940	2.70
(24) アメリカ	751	659	4,335	1,930	2.93
南アメリカ	199	37	26	0	0.01
(26) ブラジル	107	19	1	X	X
ヨーロッパ	993	407	2,750	867	2.13
(28) 西ドイツ	217	47	975	178	3.78
フランス	141	46	374	104	2.26
(30) イギリス	168	68	429	132	1.95
スイス	42	49	269	160	3.29
(32) オランダ	38	21	156	141	6.65
スウェーデン	37	2	147	34	13.59
(34) アフリカ	222	128	5	0	0.00
オセアニア	133	51	33	3	0.06

(36) 輸出件数又は輸入件数が100件以上。

Key:

1. Table 17. Key Countries in Technology Exchange (technology trade) (fiscal year 1984)
2. Key partners in trade
3. Technology exports
4. Number of cases
5. Payments received (¥ 100 million)
6. Technology imports
7. Number of cases
8. Payments made (¥ 100 million)
9. Payments made/payments received (times)
10. Total number
11. Asia (excluding western Asia)
12. China
13. Including Taiwan
14. Singapore
15. South Korea
16. Thailand
17. Indonesia
18. Malaysia
19. Philippines

[Key continued on following page]

20. India
21. Western Asia
22. Iraq
23. North America
24. United States
25. South America
26. Brazil
27. Europe
28. West Germany
29. France
30. England
31. Switzerland
32. The Netherlands
33. Sweden
34. Africa
35. Oceania
36. * The number of export cases and import cases is more than 100.

13153/8309
CSO: 4306/3040

END